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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO SPACECRAFT PROGRAM

QUARTERLY STATUS REPORT NO. 7 [U]

(Technical Review)

FOR

PERIOD ENDING MARCH 31, 1964

By Manned Spacecraft Center

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FOREWORD

This report is the seventh in a series of reports on the status of the Apollo Spacecraft Program for manned lunar landing, and reflects activities and changes in status during the first calendar quarter of 1964. This edition of this report is provided for information and for technical review.

SUMMARY

The Apollo space vehicle, consisting of the spacecraft and launch vehicle, is depicted in figure ______. The spacecraft is the responsibility of the Manned Spacecraft Center (MSC), Houston, Texas, while the launch vehicle is being developed by the George C. Marshall Space Flight Center (MSFC). The Apollo spacecraft configuration is shown in figure _____.

The Apollo spacecraft is composed of three separable modules: (1) the Command Module (CM) which houses the crew from the earth to the vicinity of the moon and return to the earth, (2) the Service Module (SM) which contains the propulsion system as well as other systems, and (3) the Lunar Excursion Module (LEM) which separates from the Command and Service Modules when in lunar orbit and descends to the lunar surface for manned exploration.

The basic launch vehicle for lunar missions is the Saturn V, which consists of three stages: the S-IC, S-II, and S-IVB. The S-IC utilizes LOX-RP-1 propellants for five F-1 engines while the S-II stage uses LOX-LH_2 propellants for five J-2 engines. LOX-LH_2 propellants are used for the one J-2 engine in the S-IVB stage.

Major accomplishments of the Apollo Spacecraft Program during this reporting period were:

1. The first two Stabilization and Control Subsystems were completed and subjected to the acceptance test procedures at subcontractor's plant. Corrective action for such deficiencies as were found is expected to be completed by April 1964, and will be reflected into design changes to the deliverable SCS, as well as the associated Bench Maintenance Equipment.

2. Two BP-19 drop tests were conducted during this reporting period at El Centro, California, in support of the BP-12 flight test at White Sands Missile Range, to check out the Earth Landing Subsystem. Eight impact drop tests were conducted with BP-1 and BP-2.

3. On February 18, 1964, North American Aviation submitted a formal proposal to MSC for a full-scale docking test program.

4. Deliveries of the first two production Environmental Control Subsystems (ECS) for BP-14 and the ECS Breadboard test vessel have slipped nearly two months.

5. The first prototype reentry battery for the Command and Service Module Electrical Power Subsystem, to be used for EDL testing, has been delivered to NAA. During this reporting period, an independent fuel cell module ran continuously for 469 hours at a load of 900 watts without malfunction. This is the first complete fuel cell module to run continuously beyond the specification life of 400 hours.

6. The first engineering models of the Communications and Data Subsystem were shipped to NAA the first part of April for integration tests. The first series of development tests on the S-band, communication, and C-band bench maintenance equipments has been completed. Motorola was awarded a contract from MSC to study the modulation scheme which is to be used on the S-band system of the CM.

7. The first gimbal actuator unit for the Service Propulsion Subsystem from Cadillac Gage was received on schedule and quality control testing of it started on February 17.

8. Two major problems of the C and SM Reaction Control Subsystem were solved, that of the delamination of the 90° ablative material for the Command Module Engine, and that of combustion instability in the Service Module engine.

9. The electric initiator and the detonator cartridge assembly of the pyrotechnics for the C/SM have been formally designated as common items for use on the LEM.

10. Operational transducers for the C/SM Operational Instrumentation Subsystem have been received by North American Aviation for Boilerplates 15 and 23. Power consumption and weight of the Signal Conditioning Equipment have been reduced from 90 watts and 47 pounds to 62 watts and 43 pounds.

11. The first experimental model television camera, using the micromodule packaging concept, was delivered to NAA for integration into BP-14.

12. The feasibility of using integrated circuit packages in the C/SM Television Subsystem instead of micromodules was determined, and a decision was made to incorporate integrated circuits in the remaining required cameras.

The new design has been approved and a breadboard model to this design was constructed.

13. Fabrication of the stainless steel honeycomb substructure panels for airframe 009 was completed at Aeronca on January 27, 1964. The definition of the Thermal Protection Subsystem for the Block II spacecraft has been studied, and the major change for this quarter is the addition of the boost protective cover over the command module. This cover is intended to protect, during launch, a thermal control coating to be applied to the ablator. The thermal control coating will result in a net weight saving of about 200 pounds.

14. Major accomplishments for the LEM Stabilization and Control Subsystem included: the award for the subcontract for the Rate Gyro Assembly to Kearfott, in a competitive source selection; completion of the procurement package for the strap-down Attitude Reference Assembly; completion of a feasibility evaluation of a shelf-mounted attitude indicator in a landing simulation; and reaching an agreement with Apollo Spacecraft Program Office and Flight Crew Operations regarding the LEM attitude controller functional requirements by the Guidance and Control Division.

15. As a result of design study, the 160-inch cantilever gear configuration for the LEM Landing Gear Subsystem was chosen in preference to the 180-inch tripod and the 160-inch lateral fold configurations.

16. Pratt and Whitney Aircraft Corporation (P&WA) reported completion of the LEM Fuel Cell Assembly design and all drawings released. The new LEM building at P&WA, South Windsor Engineering Facility has been completed and is occupied.

17. Negotiation was completed on the LEM Communication Subsystem contract with RCA and the contract was signed by both Grumman and RCA on February 25, 1964. A decision has been made to use MIL-E-6015C as a system electromagnetic interference (EMI) specification, and MIL-I-26600 and MSC-EMI-10 as a component EMI specification. This decision was made and generally concurred in at a meeting held on February 5, 1964, with representation from North American Aviation (NAA), Grumman Aircraft Engineering Corporation (GAEC), the Apollo Program Office, and the Instrumentation and Electronic Systems Division, MSC.

18. The design control specification for all propellant and pressurization components of the LEM Descent and Ascent Propulsion Subsystems, except the helium tanks and propellant quantity gaging, were released. Heavyweight rig HD-1, for descent propulsion tests, is installed in the coldflow facility at Bethpage, and is presently undergoing checkout. Rigs HD-2 and HD-3, for Rocketdyne and STL hot firing tests, have been delayed two months. Grumman studies of LEM vehicle stability during the landing phase have shown that the crushing of the descent engine radiation nozzle extension can cause vehicle instability under some conditions. The forces and loads involved in this problem are being investigated to resolve any possible conflict between engine operating integrity and the nozzle crushing requirement. The first full range (10:1 ratio) throttling test of the STL 10,500 pound engine was made. This configuration shows good combustion stability throughout the throttling range. The Rocketdyne prototype engine design, 75 pounds overweight, was released. Rocketdyne is carrying out a weight reduction program to meet the specification weight.

Injector fabrication problems for the LEM ascent engine have been resolved. The Phase "A" thrust chamber screening program for the LEM Ascent Propulsion Subsystem has been completed.

19. The primary efforts on the LEM Reaction Control Subsystem during the past quarter have involved completion of the procurement specifications for the subsystem components, the operation of the HR-1 blowdown test rig, and the completion of the construction of the cold flow test rig, HR-2. In addition, analytical and experimental investigations concerning the thermal problems associated with the Reaction Control Subsystem clusters have been completed and the results presented to MSC.

20. An evaluation of sensor and transducer requirements for the LEM Operational Instrumentation Subsystem has been completed, and signal conditioner requirements have been determined.

21. A set of specifications for the LEM television camera was prepared and submitted with a purchase request to Procurement.

22. One prototype A-3H-024 Apollo space suit was delivered in March 1964, evaluation tests were conducted, and changes and improvements to be incorporated into future Apollo suits were determined. The Apollo Portable Life Support System is being revised to incorporate the liquid transport thermal control concept.

23. During February, it was decided that the tower flap Launch Escape System design should be discontinued in favor of the canard system design, for reasons of dynamic stability among others.

24. A parametric investigation of the micrometeoroid protection requirements for Apollo has just been completed by NAA.

25. The Systems Integration Branch, Apollo Spacecraft Program Office, has completed plans for an "Electrical Power Control Program" to maintain control of energy growth for Apollo C/SM and LEM. Ground rules have been established for selection of spacecraft wiring insulation. NAA has received direction to eliminate all In-Flight Maintenance (IFM) on CM electronics packages. NAA has also been directed to prepare and maintain Interface Control Documents concerned with the spacecraft-SIVB interface.

26. A GAEC/MIT Coordination Meeting was held on February 25 and 26. The objective was to establish a jointly-agreed-upon list of functional interfaces and obtain a definition of each. Discussions were based on a ground rule of manned vehicles only. Of the 65 functional interfaces discussed, 55 were agreed to. The remainder will be written and reviewed at the next coordination meeting.

27. NAA has satisfactorily demonstrated crew transfer feasibility with the probe and drogue docking concept.

28. The general ground rules for division of functions between the Apollo Mission Simulator and the Integrated Mission Control Center have been defined. The basic booster simulation will be done in the IMCC with some body motion simulation in the AMS for certain modes of operation.

29. All data collection from the centrifuge at the Naval Air Development Center, Johnsville, Pa., has been completed. The fixture has been loaned to International Latex until April 1, 1964, to facilitate couch-suit interface studies. Major problems are in suit width and lateral expansion when pressurized.

30. Action was initiated with the Apollo Procurement Officer to implement NASA Reliability publication NPC 250-1, "Reliability Program Provisions for Space System Contractors," into the Apollo contracts with NAA, GAEC, MIT, and GD/C.

31. At the request of the Apollo Spacecraft Program Office, Grumman has initiated a special study of the mission requirements associated with the entire lunar landing mission.

32. Operational requirements have been established for the Service Module propellant dispersal system.

33. In January, a decision was reached by the ACE-S/C Project Office to provide two ACE-S/C stations for Houston instead of the proposed 1-3/4 stations, bringing the total stations to 10. Currently, GE is proceeding with making the first Houston Station a "Chinese copy" of the NAA Station, plus three consoles to handle special measurements for thermal vacuum and aero-medicine.

SPACECRAFT SUBSYSTEMS DEVELOPMENT

COMMAND AND SERVICE MODULES

Stabilization and Control Subsystem

The first two Stabilization and Control Subsystems (SCS) were completed and subjected to the acceptance test procedures at the subcontractor's plant during this period. The acceptance testing of the SCS revealed a number of deficiencies which can be roughly categorized into two groups. The first group consists of such items as phase reversals, bad components, and missing components. The contractor and subcontractor have stepped up their efforts in the quality control area. The second group of deficiencies can be classified as design problems, i.e., improper gains, nulls, or drifts. The solution to this group of deficiencies required the use of the completed hardware as a trouble-shooting tool to determine the design changes required to correct the deficiencies. Corrective action is expected to be completed by April, 1964.

The corrective action determined above will reflect into design changes to the deliverable SCS as well as the associated Bench Maintenance Equipment (BME). The contractor is studying a reallocation of subsystems to minimize the effects on scheduled deliveries.

A detailed design review of the SCS was held at the subcontractor's plant during the reporting period. The review team consisted of representatives of MSC, NASA Headquarters, Bellcomm, and technical advisors from DOD. Based on the design review, a recommendation was made that the SCS electronics be repackaged in the interest of reliability and weight.

The level 4 OMSF schedule charts for the SCS have been reworked to reflect the beginning of the qualification tests program. Additionally the entries were redesignated to facilitate identification with PERT milestones.

Earth Landing Subsystem

Two BP-19 drop tests were conducted during this reporting period at El Centro, California, in support of Boilerplate 12 WSMR abort 12. Drop test 10 simulated the flight conditions and recovery of BP-12 and test 11 lifted constraints on BP-12 configuration by utilization of redundant main parachute reefing, mortar break wires for instrumentation, and SOS spacecraft type mortar pyrotechnic cartridges. The secondary objective on drop test 11, which was to obtain dynamics during a 6-second free fall, was not accomplished due to a back-up drogue firing early. All sequential events using the BP-12 type sequencer functioned properly. Boilerplate 19 at El Centro will be modified to the Block I 009 configuration which is the two-point main parachute bridle attach and simultaneous deployed two drogues.

Considerable effort was expended toward achieving an overall weight reduction in the main parachutes. Full scale and one-third scale versions of the Apollo main parachutes were tested in the Ames 40-x 80-foot wind tunnel in February. The most promising modifications were selected and are being inexpensively tested by "bomb" drops at El Centro, California. Five "bomb" drops were conducted in March. The following main parachute modifications are being tested and evaluated:

a. Full length mid-gore vertical tapes.

b. Open ring, removal of a portion of the 5th ring from the crown apex.

c. Mid-panel skirt reefing, change of location of the reefing line retention rings horizontally to the center of each panel in the skirt.

d. Removal of four of the seventy-two gores ("conical" version).

e. Reduction of pilot chute size from 10 feet to 7.2 feet D_o.

f. Reduction of suspension line length from 123 feet to 97 feet.

The open ring, mid-panel skirt reefing and reduction in size of the pilot chute modifications have been very successful. The full length mid-gore vertical tapes resulted in the highest loads recorded to date on Apollo main parachutes and have been discarded. The removal of four gores caused unexpected large oscillations. Reduction of suspension line length has yet to be tested in this series. The open ring modification has reduced the system oscillation significantly. The parachute swing angle reduction has been one of the objectives of this program due to the criticality of C/M impact attitudes into water.

The series of environmental proof tests for the backup BP-12 earth landing subsystem sequencer showed a problem with the baroswitch components. The narrow deadband or hysteresis allowed by the specification caused the design to be critical to vibration. A wider deadband would allow the main parachutes to be deployed at excessive altitudes up to 20,000 feet after certain abort conditions. Because of these facts, a wider dead band baroswitch will be used on BP-12 and spacecraft which is not critical to environment and the main parachute deployment altitude will be reduced from 15,000 feet to 12,000 feet which will reduce the maximum deployment altitude for all abort conditions.

A total of eight impact drop tests were conducted with BP-1 and BP-2. There were seven tests into water and one test on soft packed soil. The water tests were conducted to determine pressure time histories and crew couch load data. The land test was conducted to further define the soil impact system capabilities.

The decision to go to water landing as the primary mode was made in January. Minor modification to the crew couch attenuation struts and test program are being made due to this decision.

Impact tests with BP-2 into water and consideration of higher than anticipated parachute angles (±20° for two main chutes) at impact resulted in questionable structural integrity causing leaks in the C/M. Structural analysis indicated problems at impact angles less than 15°. Adequate data will not be available to fully define this problem until tests are made with boilerplate 28 scheduled to start in August of this year.

The canard abort configuration concept was accepted and implemented to NAA in January. The Engineering and Development Directorate completed a canard boilerplate type flight hardware in March 1964 for possible use on BP 12. The detail design was furnished to NAA. Minor design modifications were made to the MSC design. NAA, S and ID has completed the initial canard design layout and has released this to NAA, Los Angeles Division for detail design and fabrication. It is expected that it can be completed for testing on BP 23 at WSMR.

Docking Subsystems

On February 18, 1964, North American Aviation (NAA) submitted a formal proposal to the Manned Spacecraft Center for a full-scale docking test program. NAA proposes to construct full-scale vehicles that represent the command/service module, the lunar excursion module, and the LEM/S-IVB spacecraft configurations. The proposed vehicles are to be supported by a Levapad, air-suspension system and vehicle motion is provided by a series of air-jets that simulate the spacecraft reaction control system. The test vehicles will provide the capability for yaw-plane, dynamic testing of the Apollo docking subsystem for the precontact, contact, post-contact, and separation phases of the docking sequence.

Environmental Control Subsystem

Delivery of the first two production environmental control systems (ECS) for Boilerplate No. 14 and the ECS Breadboard test vessel has slipped from the end of March and April, respectively, to May 21 and June 29, 1964, respectively. A combination of minor problems caused these delays, predominant among which was a longer than anticipated assembly time for the major ECS package.

The component-level qualification test program was begun by AiResearch during this period. A total number of sixty-three components will be tested, and NAA has established a permanent task force at AiResearch to expedite review and approval of acceptance and qualification test procedures.

Installation and checkout of the interim-configuration ECS has been satisfactorily completed for the unmanned series of ECS development (Breadboard) tests. Several failures were encountered with the ECS hardware during the checkout phase which were attributed to the fact that the subject hardware was development rather than production equipment. The chamber test facility and test article are now ready for unmanned testing.

The North American Aviation measurement requirements for Airframe 008 have been reviewed and coordinated with the CSD test requirements. A memorandum recommending CSD measurement requirements has been submitted to the Spacecraft Test Branch of the Structures and Mechanics Division.

MSC E and D has partially completed an evaluation of urine boiling in a prototype model of the Apollo C/M glycol evaporator. Test results to date indicate that a degradation in performance of 27.5 percent was experienced for the three urine tests performed. In addition, a marginal degree of clogging occurred in the porous plate (water-gas barrier) after the 100 hour test, signifying that solids removal will be required if urine boiling is implemented.

Electrical Power Subsystem

Power distribution.-

Reentry Battery - The first prototype, which will be used for EDL testing, has been delivered to NAA.

NAA has reduced the minimum battery voltage requirement from 27 volts to 26.5 volts, during 35 amps discharge at 50° F. Since the 26.5 volts only exists for a short duration (approximately five minutes) there will not be any adverse effects on the spacecraft systems.

Pyro Battery - Electric Storage Battery Co. (ESB) could not meet the design requirements of delivering 90 amps for 30 seconds, within the present specified battery dimensions. After an investigation, NAA relaxed the required capacity to 75 amps for 36 seconds.

Inverter - Westinghouse has started testing on the verification units. These units are identical configurations to the prototypes with the exception of their base plates which are constructed of aluminim instead of magnesium.

Battery Charger - ITT has shipped the prototype units for BP-14 and AFRM-006 to NAA. These interim units, which do not contain high reliability components, will be replaced by qualified units at the completion of qualification testing.

Sequencer - A design review of the BP-12 and BP-13 sequencer was held March 27, at NAA. As a result of the review, the sequencer was modified as follows:

(1) Elimination of single point failures, by the addition of a relay in the circuitry.

(2) Because of the modification, a flight unit will not be available until April 22, 1964.

Fuel Cells.-

During the reporting period an independent module ran continuously for 469 hours at a load of 900 watts without malfunction. This is the first complete fuel cell module to run continuously beyond the specification life of 400 hours. This module was shut down because of performance decay due to dendritic growth. Dendritic growth has become more of a problem with the accumulation of longer test times. This problem area is being thoroughly investigated. Improvement of bond strength between sintered electrode particles and coating of the electrodes or diaphrams show promise in reducing effects of dendritic growth.

Effort in seal development has reduced creep in the Teflon seal to about 5 percent, which is an order of magnitude reduction. Well over 2000 hours of multi-cell testing have occurred without any shorting or leakage caused by seal failure.

Modifications to startup and shutdown procedures to increase electrolyte bond strength have reduced the incidence of cell "ballooning". Other areas under investigation to reduce cell "ballooning" include improvement in electrode quality control, improved cell handling precedures, and reduction in cell stack temperature gradients.

Incidence of reactant tube plugging has been reduced by a number of modifications such as coined sinters, larger reactant tubes, and controlled carbonate fill. These fixes were incorporated on the module that ran 469 hours and a six cell stack that ran over 1000 hours without plugging problems.

High module heat rejection has prevented attainment of minimum self-sustained power of 563 watts. Numerous insulation modifications as well as lower hydrogen and glycol coolant flows are being investigated. Minimum powers of as low as 505 watts have been achieved with reduced hydrogen flow rates but at these rates, required continuous operation above maximum normal power levels is not possible.

North American Aviation (NAA) completed three tests on the first prototype "A" module to be delivered. A total load time of 112 hours was accumulated before the test was terminated prematurely because of a sudden drop in output. The cause of malfunction has been attributed to electrolyte flooding that was caused by delamination of an electrode. The specification life of a prototype "A" module is 100 hours. Following this single module test, NAA ran two modules in parallel for a programed 5 hour test of load sharing at various loads. The maximum difference in current sharing between the modules at a total load of 100 amps was 2 amps. Additional load sharing tests are scheduled by NAA.

Three prototype "B" modules are scheduled for delivery early in April 1964.

The following table is an accumulation of test hours at Pratt and Whitney as of March 31, 1964.

Configuration	Test hours	
	At Temp.	On Load
Single cells	82,000	44,000
6 cell stacks	8,730	5,820
31 cell stacks	8,820	4,850
Independent modules	13,050	6,950

Cryogenic Storage.-

Development testing at Beech Aircraft during the reporting period was concentrated in attempting to reduce the heat leak in the hydrogen and oxygen tanks. Changes in minimum spacecraft power levels enabled specification maximum heat leak requirements at 130°F to be increased from 6.2 BTU/HR to 7.5 BTU/HR for the hydrogen and from 16 BTU/HR to 22.5 BTU/HR for the oxygen. The heat leak on the hydrogen tank has been reduced from 23.9 BTU/HR to 11.9 BTU/HR through the use of improved insulation with vapor cooled shields. Additional modifications such as changing electrical wire material and improved coil cover insulation are now being made to further reduce heat leak. Tests results are expected in early April 1964. Similiar modifications are also being made to the oxygen tank. Preliminary data indicates that the O_2 tank heat leak has been reduced from 32 BTU/HR to 23. BTU/HR with only a partial vacuum. Beech predicts the heat leak will drop to about 20 BTU/HR when the proper vacuum is achieved.

Hydrogen titanium pressure vessel forgings were found to have grain sizes of 2 to 3 instead of the required 5 or finer. In addition, the pressure vessels welded for pressure vessel qualification burst tests did not have 100 percent internal weld land consumption as required by the specification. Although it was the consensus of the metallurgy experts concerned that these discrepancies would not affect structural integrity, the first qualification vessel was designated a development article since it was the first burst test. This vessel burst at 1134 psi at -368°F but post test calculations indicate that burst should have occurred at about 1300 psi. Test data showed that creep may have occurred during a hold period of 12 minutes at 920 psi while the vessel was being pressurized. Both Beech and NAA metallurgists are investigating this problem.

Tests on the oxygen Inconel destruct forging have been completed. Preliminary analysis of the data indicates that the material meets specification. Machining of the Inconel forgings has begun at both machining vendors.

Development testing of the fan motor heaters was successfully completed. The fan motor heater configuration has now been incorporated in place of the previous concentric sphere heaters.

Present weight of the cryogenic system is now approximately 330 pounds versus a specification weight of 309 pounds. Most of this weight increase is due to the insulation modifications which also required heavier outer shells.

Communications Subsystem

Pulse Code Modulation (PCM) Telemetry.-

a. E-1 Model has completed RFI testing, vacuum tests, and pre-qual testing.

b. E-2 Model presently being used by Radiation, Inc., in their testing for system grounding problems.

c. E-3 Model being used by Radiation, Inc., for humidity testing.

d. E-4 Model completed system tests and is awaiting approval of acceptance test procedures.

e. E-5 Model is undergoing system tests at Radiation, Inc.

f. E-6 Model is presently being assembled.

g. All D-models assembly and testing being held up until the humidity problem is resolved.

Premodulation Processor (PMP).-

a. E-1 Model is at NAA, Downey, California, for system tests and performance analysis.

b. E-2 Model is undergoing EMI and temperature tests at CRC.

c. E-3 through E-6 are in production at CRC.

d. No major technical problems are presently being encountered.

Up-Data Link - Digital.-

a. Parts procurement for all E-models completed.

b. Manufacturing of E-model modules held up due to lack of resolution of NAA/NASA quality assurance requirements with respect to soldering and welding.

c. Contract let to Motorola, Inc., Scottsdale, Arizona, for UDL Bench Maintenance Equipment.

d. D-model parts specifications sent to NAA for approval and released to vendors for bids.

C-Band Comparator.-

a. E-1 Model shipped to NAA from ACF on April 1, 1964.

b. E-2 Model completed shock tests and is presently undergoing vibration tests.

c. Slippage in delivery schedules of C-band comparator is attributed to ACF's changes from GE transistors to Fairchild transistors.

d. Thermal analysis is presently being performed on E-2 Models by CRC and ACF.

VHF Beacon.-

a. E-1 Model complete and being shipped to NAA.

b. E-2 Model undergoing EMI tests.

c. E-2 Model temperature tests revealed a low power condition at high temperatures.

d. D-Model redesign is now in progress.

VHF-AM, VHF-FM, HF Equipment.-

a. E-Models and dummy SEP equipment shipped to NAA. These shipments late due to clarification of shipping requirements and technical documentation

b. Pre-qualification and part application testing continued.

Audio Center Equipment.-

a. E-1 Model shipped to NAA.

b. E-3 scheduled for completion this report period and delivery to NAA May 25, 1964.

c. First D-Model scheduled for completion next quarter.

S-Band Transponder.-

a. E-1 Model currently in preliminary design proof tests (vibration).

b. E-2 Model awaiting delivery to NAA for BME checkout.

c. E-3 Model at CRC scheduled for BME compatibility tests and system integration tests.

d. D-Models procurement of high reliability parts now in progress.

C/S Module Earth Sensor Status.-

Using the following definitions:

E - breadboarded engineering model.

D - temperature rated engineering model.

P - production model (complete).

There will be no E-infrared sensor built.

Instead, the D-model will be designed and built without benefit of an E-model.

At present, the D-model is estimated to be 75% complete. The completion data should be around May 15. It is not known when a P-model will be started.

VHF Multiplexer.-

a. E-3 had acceptance tests completed 1-21-64.

b. E-2 had development test completed 1-14-64.

c. E-2 and E-3 had humidity tests completed 1-6-64.

SCIN Antenna.-

a. SCIN mod acceptance tests completed 1-28-64.

b. SCIN antenna parts available for assembly 3-6-64.

c. SCIN antenna, Model D, fabricated on 3-21-64.

d. Final design of SCIN antenna completed 1-20-64.

e. Fabrication of engineering qualification test model of SCIN antenna was completed 1-24-64.

f. Fabrication of mechanical model, E, SCIN antenna was completed 3-6-64.

- The first Engineering models of the Communications and Data Subsystem wer shipped to NAA the first part of April for integration tests.

- The first series of development tests on the S-band, communication, and C-band bench maintenance equipments has been completed. Brassboard models of the spacecraft equipment were utilized to perform these tests.

- Motorola was awarded a contract from MSC to study the modulation scheme which is to be used on the S-band system of the CM. Release of S-band spacecraft equipment has been accomplished in connection with this contract.

- Dorne and Margolin (D&M) has been awarded a contract by MSC to investigate the feasibility of flush-mounted CM antenna systems. D&M is working closely with NAA in connection with this contract.
- Proposed changes for the Block II communications configuration are in the final stages of negotiation.
- In-flight spares will not be carried to support the Communications and Instrumentation System. The In-Flight Test System (IFTS) capability is being modified accordingly.
- The C&SM rendezvous radar antenna location has been tentatively selected.

Service Propulsion Subsystem

The Phase I (development) tests at the Arnold Engineering Development Center (AEDC) were scheduled for completion on March 28. However, due to the desire to complete a duty cycle run, testing will continue into April. Twenty-three altitude firings to evaluate facility modifications and obtain engine design data were conducted. During one of these tests (mixture ratio survey), the engine went rough at ignition. The average "g" level was 150 g's with peaks of 300 g's. The engine was removed and testing continued. The rough combustion monitor parameters were changed to make the device more sensitive to vibration.

Research and Development efforts are being pursued to develop a baffled injector. At present the baffled injector is giving promising performance. Eight bomb tests have been conducted on brazed baffled injectors with 150 and 159 grain bombs. Pressures above chamber pressure of as high as 226 psi have been recorded. All induced oscillations dampened within 18 m seconds. Further testing is planned. Production of unbaffled injectors will be terminated when the baffled injector is considered suitable for prequal and qual testing.

Problems with the combustion chamber have been leakage between the injector-chamber flange and severe chamber erosion. The leakage has been corrected by applying an epoxy resin to the seal. Two tests have been conducted on the engine with the epoxy resin. No leakage occurred. Thrust chamber erosion is attributed to a 600 cps oscillation with an amplitude of $\pm$ 5 to $\pm$ 10 psia. The 600 cps oscillations have been observed on practically all thrust chamber unbaffled injector component tests.

SPS oxidizer tank Number 5 was accidentally damaged during qual testing. An investigation revealed that the tank had wrinkles in the cylindrical section but was still within specification. Due to the two-month fabrication time for a new tank, qual testing will continue with the wrinkled section marked. Should a failure occur within this section, the contractor has been requested to conduct a complete investigation to determine whether the failure was random or due to qual testing. Completion of qualification testing of tank Number 5 should be complete by mid-May.

Delivery of the first gimbal actuator unit from Cadillac Gage was received on schedule. Quality control testing started on February 17. The required performance of the first Cadillac Gage unit was met in all areas except force gain (3.0 lbs/MA required 3.57 lbs/MA actual). Acceptance tests are scheduled to be completed on April 1 and prequal test on April 15.

Two major problems have been encountered with the helium regulator valve: pressure spikes when the upstream solenoid valve is opened and excessive leakage. An anti-surge device was placed downstream of the primary stabilizer. Testing has verified that the pressure spike has been corrected and that the anti-surge device is not needed on the secondary stabilizer. The leakage problem is being investigated; however, the area of leakage has not been isolated. It is believed that the primary controller is causing the problem. A new seal material is being investigated.

Reaction Control Subsystem

Command Module - The primary effort during the past quarter has been with the engine development program at Rocketdyne. At the end of the last quarter, three major problems were evident:

a. Delamination of the 90° ablative material

b. Cracking of the silicon carbide throat insert

c. Glassing and erosion of the chamber

Programs have been initiated to solve each of these problems.

The use of a 45° oriented ablative billet has solved the delamination problem. A throat insert evaluation program has been initiated. Pre-charred ablative throats have been tested and eliminated from further consideration. A JTA graphite throat has been tested and found to experience little erosion. This is a brittle material however, and has experienced some cracking which occurs as a result of thermal and mechanical loads. A design effort to eliminate the cracking of this material is continuing. The problem of glassing and erosion of the chamber wall has been shown to be the result of improper propellant injection. Lucite (Plexiglas) chambers have been tested using three of the previously tested injectors. One of the three has been found to submit the chamber to excessive localized heating. Seven other injectors are to be tested. It is expected that these tests will reveal the cause of many of the previously experienced chamber failures and indicate the required degree of quality control on the injector assembly.

<u>Service Module</u> - The primary effort during the past quarter has been with the engine development program at Marquardt. At the end of the last quarter, two major problems were evident:

1. Combustion instability
2. High pressure transients during ignition (spiking)

The combustion instability problem was found to be caused by two phase flow in the injector oxidizer passages. This has been eliminated by streamlining the hydraulic design and limiting heat transfer in the oxidizer flow passages.

The spiking problem has resulted in failure of the refractory metal combustion chamber. An attempt to eliminate this failure mode by strengthening the chamber was unsuccessful. The present emphasis is toward elimination of the spiking phenomena by modification of the injector and/or by the use of propellant additives. Other materials are also being investigated as possible replacements for the molybdenum. A secondary problem has been with development of a Teflon bladder for positive expulsion of the propellants. However, these development problems have been based on essentially unrealistic fill procedure requirements. The fill procedures are being changed to accommodate the bladder life requirement.

Launch Escape Propulsion Subsystem

The Launch Escape System (LES) provides the means of propelling the Command Module to a safe attitude and position in the event of a pad abort or a suborbital abort. The Launch Escape Propulsion Subsystem is comprised of the three rocket motors (Launch Escape, Pitch Control, and Tower Jettison) in the LES.

Launch Escape Motor.-

Four Launch Escape development motors employing 31% of ground oxidizers were statically tested by Lockheed Propulsion Company (LPC) during the reporting period. Three of the motors tested performed satisfactorily; however, motor ED-30 tested February 10, 1964, experienced a maximum thrust value above the maximum allowable value. In an effort to justify the high thrust value, LPC instrumented a development Launch Escape motor with thermocouples and simulated the conditioning temperatures of motor ED-30 in order to more accurately estimate the true conditioned temperature of motor ED-30. LPC determined that the actual temperature of motor ED-30 was approximately 6° F above the maximum temperature specification value. LPC also determined that motor ED-30 would have been above the specification value if the motor had been conditioned to the maximum temperature specification value. North American Aviation (NAA) and LPC will make a presentation to NASA on April 1, 1964 giving summary performance information from the Launch Escape Motor Development Program and recommended corrective procedures for resolving the maximum thrust problem. The Qualification Program for the Launch Escape Motor has been delayed until corrective action on the maximum thrust problem has been taken.

NAA stated in their memorandum 64MA2975 dated February 28, 1964, that NAA and LPC will not inspect the propellant grain of the Launch Escape motors at WSMR unless "tie down" facilities are furnished to secure the motor during the procedure. NASA MSC is presently reviewing the necessity and justification of such a facility.

Pitch Control Motor.-

Two Pitch Control development motors employing 31% ground oxidizer were statistically tested during the reporting period. Both tests were satisfactory.

As the Pitch Control motor uses the same propellant mixture as the Launch Escape motor, the Qualification Program for the Pitch Control motor will be delayed until the problems associated with the Launch Escape motor are resolved. No manufacturer or performance problems are being experienced with the Pitch Control motor.

Tower Jettison Motor.-

The igniter boron pellet basket problems experienced by Thiokol have been solved. Thirteen pyrogen tests using a redesigned pellet basket were successfully conducted during March, 1964. The new design incorporates a thicker basket screen and uses the type 2A initiator cartridge that is used in the Launch Escape motor. One Tower Jettison motor test was also conducted using the redesigned pellet basket.

Thiokol Chemical Corporation is ready to begin the Qualification motor program. Delays may be experienced in the Qualification program, pending decisions on the use of a booster protective cover for the Command Module. The use of such a cover would necessitate changes in the thrust vector offset angle.

Pyrotechnics

General - The electric initiator and the detonator cartridge assembly have been formally designated as common items for use on the Lunar Excursion Module (LEM). All other pyrotechnic device specifications are being reviewed to determine whether other devices can be so designated.

Apollo standard initiator - The static sensitivity problem appears to have been solved; a lot of 25 units successfully passed a test of 11, 000 volts (requirement is 9, 000 V). The internal pressure capability is approaching the goal of 30, 000 psi. During the next quarter the initiator will be environmentally tested and then will undergo the final design verification tests prior to qualification testing.

Apollo standard detonator - The charge (RDX and lead azide) has been established. The device performs satisfactorily in various devices and systems. Tests have been successful using detonators and linear shaped charges (LSC) at various relative orientations to free system designers from most restrictions on the detonator - LSC interface. The detonators are now acceptable for flight on BP-12.

Launch Escape Tower Separation System - Difficulties have been experienced in obtaining cross-detonation of the two charges of the dual mode bolt under all conditions. The most probable failure mode is that one linear shaped charge could dud the other under a particular combination of conditions. A development test program to solve these problems has begun. Because of these difficulties delivery of the first flight articles has slipped to June 1964 and single mode bolts are being used on BP-12, BP-13, and possibly BP-15. Adoption of the canard to eliminate the forward trim point eliminates the tower-to-motor separation plane.

<u>Command Module - Service Module Separation System</u> - Charges for cutting the tension ties and the umbilical have been established at 100 gr/ft (RDX). Tension tie cutter assemblies for BP-12 constraint and development tests have been ordered; constraint tests are scheduled to be completed April 15, 1964. Design of the circuit interrupter has been completed. This device dead faces critical circuits upon separation of the modules.

<u>Service Module - Adapter Separation System</u> - Of the several concepts tested, mild detonating fuze (MDF) fracturing reduced sections of the splice plates appears to be the best since no objectionable fragmentation is present. Thrusters will probably provide initial motion of the panel segments. Design freeze is scheduled for May 1964. Tests to date indicate a probable MDF density for cutting the splice plates to be in the area of 10 - 15 gr/ft.

<u>Adapter - LEM Separation System</u> - North American Aviation (NAA) is proceeding with tests to size the charge required for severing the tension straps.

<u>LEM - Command Module Separation System</u> - When the LEM and Command Module (CM) are docked, a pyrotechnic separation system is

employed. Two system concepts are being studied, viz., LSC cutting the structure and MDF failing bolts in tension. The latter offers advantages in that no sharp edges are left, structure is completely removed, and there are no high velocity particles.

Forward Heat Shield Jettison System - Adoption of the canard system for abort turn-around in lieu of the tower flap configuration returns the forward heat shield weight to the original figure and eliminates considerable testing necessary to size the charges and plumbing. Further, it assures that jettison occurs when the CM is in the most favorable attitude, i.e., aft heat shield forward, and reduces the aerodynamic forces against which the thrusters must act to a minimum. Also, on a pad abort, the tower jettison motor removes the forward heat shield, giving maximum time for parachute deployment.

Service Module Propellant Dispersal System - The Atlantic Missile Range Safety Office has accepted the concept of adapter-mounted conical shaped charges firing into the tankage contingent upon successful demonstration of the system capability to effect propellant dispersal. This system minimizes effective weight and maximizes crew safety. The four charges are mounted on the upper part of the four adapter panels, and aimed at the tankage, each charge penetrating one oxidizer and one fuel tank for redundancy. When the Service Module is separated from the adapter and the panels outwardly rotated about a lower hinge point, the attached charges point in a rearward direction (away from the Command and Service Module (C and SM)) and are left behind with the adapter and last stage booster.

Range Safety requires radio command receivers for this system but will consider a waiver permitting interconnect with the S IV B destruct system based on a thorough analysis of the structure from lift off to a point where hazard to land masses no longer exist. An interconnect would be desirable from a weight standpoint but the complexity of the analysis may present scheduling problems. The NAA development schedule permits no slippage if the system is to be qualified and used on AFRM 009; acceptance of the conical charge concept permits NAA to proceed with development of the pacing item (the charge). A decision on the question of independent versus interconnected systems is expected in April 1964.

Earth Landing System components - In the mortar cartridges (drogue and pilot) the problem of debris from the end closure has been solved. Firings of cartridges in ground mounted mortars resulted in a wide scatter of data points when pack velocity was plotted against reaction loads. The cause is believed to be the combinations of variables in the mortar system rather than variation of output of the cartridges. Orifice diameter, pack density, friction, temperature, and possibly instrumentation, and the tolerances involved, are suspected to contribute to the anomalies. Analysis of the structure and mortar mounts indicate that there is no problem with BP-12 at the present reaction load levels, hence the cartridges will be used on that flight in their present configuration. The Manned Spacecraft Center (MSC) has requested that a development test program controlling the variables be conducted to isolate the causes and explain the anomalies.

The drogue disconnect which experienced difficulties in its early configuration and with the first detonators available has been reworked. The new configuration detonators will be used to actuate devices for BP-12.

The main parachute cluster disconnect has been redesigned and will undergo tests in the near future. No disconnect will be used on BP-12.

Launch Escape System components - The configuration and loading of the Type I igniter cartridge (for pitch control and launch escape motors) was established early in the quarter. Design verification tests were successfully completed.

Difficulty was experienced in developing the Type II ignition cartridge (for the tower jettison motor) in that the pellet basket of the pyrogen unit was damaged. After several propellant loadings were tested the cartridge was frozen at the same loading as the Type I; the thread size is different and the initiator connector will be indexed differently to preclude installation in the wrong motor and connection of the wrong firing circuit. Thiokol Chemical Corporation is modifying the pellet basket to assure that the problem has been solved. Since, with these exceptions, the two cartridges are identical, the Type II is considered to have completed design verification testing.

Both Types I and II are satisfactory for the BP-12 flight.

CM Reaction Control System components - Tests to assure adequacy of performance of the one-fourth inch helium valve using the standard initiator as the pressure source are being conducted. The propellant charge for the booster cartridge of the five-eighths inch propellant valve is being experimentally determined. Several means for eliminating the single failure problem in the propellant dump system, discussed last quarter, are being considered.

Recovery aids - The SOFAR bomb used in Project Mercury has been selected for Apollo use; it will be qualified and supplied as Government furnished equipment. Manually actuated flares are also being qualified and will be GFE.

Miscellaneous devices and studies - A pin retractor has been selected as the release mechanism for the high gain antenna deployment function. Proximity of the antenna and release point mitigates against the use of high explosives.

MSC is investigating whether newly manufactured ("virgin") RDX or material commercially reclaimed from warheads is better for use in the Apollo high explosive devices. While there are undoubtedly differences in initiation sensitivity, brisance, impurities, etc., their effect must be determined. Other newly developed high explosives such as TACOT, HMX, and DIPAM, as well as PETN are also being considered.

A difference in requirements of the WSMR and AMR for disposition of unused bridgewire circuits in the initiator is now presenting a problem. WSMR requires that unused bridges be shorted and grounded while AMR has no such requirement. Current NAA Apollo design practice is to leave the bridges on open circuit. Since there are a number of factors to be considered, the temporary MSC (Engineering and Development Directorate) position is that the circuits shall be left open but that the WSMR requirement be accepted for BP-12 only under protest and as an expediency. A firm MSC position will evolve from the current study of the following possibilities:

a. Circuits open (current NAA design)

b. Circuits shorted pin to pin only in the connector

c. Circuits shorted and grounded pin-to-connector-to-pin (WSMR requirement)

d. Circuits shorted and grounded pin-to-pin-to pyro negative (completely in connector or at pyro battery negative)

A requirement has been established that initiators, and devices with integral (factory assembled) initiators be shipped, stored, and installed with shorted mating electrical connectors installed. Since these connectors cost about seven to ten dollars each, their re-use is desirable. MSC is investigating the possibility of obtaining a suitable substitute device of low cost which can be classed as expendable.

A potential problem in obtaining the required simultaneity of functioning a number of devices has been discovered. Variation in sequencer operating times, pressure buildups and the tolerances involved are contributing factors. The effects, their implications and possible solutions are being investigated.

Operational Instrumentation Subsystems

Operational transducers have been received by North American Aviation (NAA) for Boilerplate 15 and 23.

Power consumption and weight of the Signal Conditioning Equipment (SCE) has been reduced from 90 watts and 47 pounds to 62 watts and 43 pounds.

An engineering model of the Central Timing Equipment (CTE) has been received. The mechanical and electrical configuration has been changed by the addition of a mother board and by redesign of the power supply and oscillator to improve reliability and meet increased power output requirements.

Several problems with the data storage equipment (DSE) were solved. Among these were deterioration experienced in high humidities, and flutter. An engineering model of the DSE (E6) has been received byNAA and is undergoing acceptance testing.

Meetings were held at NAA on February 13, and at Houston on April 2, 1964, to discuss the heat shield instrumentation development program. The purpose of the meetings was to establish common test conditions and procedures for simulation of reentry conditions. This is a result of a joint agreement by MSC-IESD and NAA that a common reference would allow comparative analysis of data for proving the hardware designs.

The status of operational transducers has improved during the reporting period due to the application of recovery techniques. Typical of the improvement is the reduction of expected delivery of transducers to manufacturing for AFRM 008 from 50 weeks to 34 weeks late. This is due to a late definition of requirements and not to technical problems. However, operational transducers are not a pacing item and will not have a schedule impact.

Television Subsystem

A study of the feasibility of changing the basic electronic packaging concepts of the television camera was completed by the subcontractor. This study was initiated because it appeared to the subcontractor that the micromodule packaging concept would be too expensive and would have design limitations which would increase the cost and delay flight qualification of the equipment. The feasibility of using integrated circuit packages instead of micromodules was determined. A decision to incorporate integrated circuits in the remaining required cameras was made. A new design implementing this decision was prepared, analyzed by North American Aviation (NAA) and Instrumentation and Electronic Systems Division (IESD), and approved. The breadboard model of this new design was constructed and procurement of parts for the first experimental model was initiated.

The first experimental model television camera was delivered to NAA. This model uses the micromodule packaging concept.

Revision C of the procurement specification was prepared and submitted to the subcontractor as the basis for negotiation of the final definitized contract.

The bench maintenance equipment design was completed and approved. The prototype model of this equipment was constructed and checked out.

The procurement specification for the five-foot cable which allows television of views from the cabin windows was completed and released.

The subcontractor prepared a proposal for designing the camera to withstand 100% humidity and salt spray. This proposal, containing cost, scheduling, and design information is under analysis by NAA.

A decision was made to carry the zoom lens in an environmentally qualified box in order to relax the requirements on the lens. This allows a considerable saving in cost of the lens.

The first experimental model of the intended final flight configuration is under development. This television camera will incorporate integrated circuit packaging concepts. Developmental testing of this camera will begin during the next quarter.

An earlier experimental model, not of final flight configuration, is at North American Aviation (NAA) awaiting integration into Boilerplate No. 14, the NAA house spacecraft. This model contains the obsolete micro-module packages and cannot be flight qualified; however, it is of the final external physical configuration and has many of the final performance characteristics. Mechanical fit of this camera and required illumination levels within the spacecraft will be determined during the next quarter.

Radar Subsystem

The common usage requirement of the LEM and C/SM rendezvous radar is complicated by the LEM requirement to track a corner reflector or beacon on the lunar surface and the different thermal and interface problems.

The antenna location on the C/SM is not firm. The location has been tentatively selected; however, the cooling, power, and structure information is still incomplete due to the lack of a firm design on the LEM rendezvous radar.

Instrumentation/Communication R and D Subsystem

During this report period the Instrumentation and Electronic Systems Division (IESD) has continued effort to deliver instrumentation/communication (I/C) R and D Government furnished equipment (GFE) to North American Aviation (NAA) for the following vehicles:

Vehicle	Delivery Schedule to NAA
Boilerplate 22	July 7, 1964
Boilerplate 22 Special System	October 1, 1964
Airframe 002	December 1, 1964
Airframe 010	January 1, 1965
*Airframe 006	January 1, 1965
*Airframe 008	September 8, 1964
*Airframe 009	August 8, 1964
*Airframe 011	October 30, 1964
*Boilerplate 14	January 1965

*Requires telemetry systems only.

As of this report period, the above programs are generally on schedule. In some cases vendor deliveries to MSC and rejected hardware may result in minor slippage of the above delivery schedule.

IESD is continuing engineering I/C R and D liaison support for BP-15 and BP-23 systems at NAA to insure timely and effective resolution of all problems. In addition, field liaison was provided at the launch sites for BP-12 and BP-13 R and D instrumentation/communication systems.

Boilerplate 13 engineering change order was incorporated at Atlantic Missile Range (AMR) on the I/C system to accommodate new calibration components required due to late program accelerometer range changes.

In order to assure attitude gyro data after abort, Boilerplates 12 and 23 gyros will be uncaged by the abort signal. Excessive roll of the booster will cause gyros to lose their reference if uncaged prior to liftoff.

As a result of an ASPO-IESD-NAA task team investigation, NAA was directed to make necessary design modifications on the BP-12 mission sequencer to eliminate single point failure possibilities. The significance of a failure would be (1) during count down - potential injury to launch personnel, (2) immediately after liftoff - mission failure. Upon completion of the modifications, NAA will perform a complete flight qualification program.

A recent investigation and analysis of the BP-12 and BP-13 Minimum Airworthiness of contractor furnished equipment (CFE) revealed several electrical items which either have not met test requirements or the requirements tested to are not compatible with the expected mission profiles. MSC and NAA are taking expedient action to resolve these problems.

Due to the cancellation of the BP-18 program, IESD has received official approval of ASPO to utilize all I/C GFE hardware in support of other program areas as may be required.

Scientific Instrumentation Subsystem

Weight and volume allocations for scientific equipment in the Command Module have been reduced to 80 pounds and two cubic feet; on lunar landing missions it is anticipated that this weight and volume will be utilized for returning lunar surface samples and data transferred from the LEM. The total spacecraft allocation of 250 pounds is discussed under the Lunar Excursion Module scientific equipment.

In-Flight Test Subsystem

The Systems Engineering Division of ASPO has recommended that the IFTS be retained, but with a reduced confidence-level monitoring function only. This recommendation is based on the assumption that no additional crew display panel space is available, and some monitoring for failure detection will be required.

Thermal Protection Subsystem

Fabrication of the stainless steel honeycomb substructure panels for airframe 009 was completed at Aeronca on January 27, 1964.

A series of fabrication and assembly problems have been encountered with respect to the stainless steel fabrication, both at Aeronca and at NAA. Problems in the brazing of the PH14-8 Mo stainless steel have appeared at Aeronca. However, these have been overcome, and full production was achieved by the end of March. Assembly tooling at NAA was found to have dimensional and location inaccuracies, and much of the tooling was taken off line for rework. It is anticipated that all this tooling will be back in operation early in the next quarter. Castings for the tower leg wells have proven to be a continuing problem with good quality control not obtainable.

The definition of the Thermal Protection Subsystem for the Block II spacecraft has been studied during this reporting period, and the major change is the addition of the boost protective cover over the command module for the purpose of protecting during launch a thermal control coating which will be applied to the ablator. This coating will provide an α/ϵ ratio of .4 and produce ablator temperatures not in excess of 100°F at the start of entry. This will result in a net weight saving of about 200 pounds due to the "cold" start and the deletion of boost ablator protection.

The ablator cracking problem at the cold soak condition has been studied extensively. Specimens which had cracked spontaneously under cold soak have been tested in tension and compression, and in no cases did cracks widen prior to failure of the steel substrate. No bond failure or delamination has resulted on any tests to date.

The flight entry test of the AVCO 5026-39 HCG ablator on a five stage Scout payload is now scheduled for June.

Trial manufacturing of the ablator on dummy substructure components has been completed for the forward compartment and a segment of the aft compartment. In general, satisfactory application of the honeycomb core and edge members and successful gun filling of the ablator into the core has been achieved. Techniques for both minor and major repairs have been explored and developed satisfactorily. Work is proceding on the trial application of ablator to the more complex crew compartment.

Mission Programer Subsystem

NAA and Bellcom have completed the first phase of a design study to investigate the feasibility of conducting unmanned Apollo earth orbital flights. The study indicated the feasibility of utilizing the AGC as a prime systems sequencing device.

LUNAR EXCURSION MODULE

Stabilization and Control System (SCS)

The subcontract for the Rate Gyro Assembly (RGA) has been awarded to Kearfott in a competitive source selection.

Negotiations were begun with RCA for the Attitude and Translation Control Assembly (ATCA) procurement during this reporting period. A go-ahead is anticipated for late April or early May.

The procurement package for the strap-down Attitude Reference Assembly (ARA) was completed this reporting period. Requests for bids from industry were planned for early April with subcontract award anticipated in June.

The level 4 OMSF charts were updated to reflect the revised LEM program. The PERT does not as yet completely reflect this program. Further detailed work is planned to aline the OMSF charts and PERT with the new program.

A feasibility evaluation of a shelf-mounted attitude indicator has been completed in a landing simulation conducted by the Guidance and Control Division. Results showed this type indicator to be useful and flyable in a landing simulation although it is not a familiar display. Significant power, weight, and reliability advantages are offered by this display over the more conventional panel mount because of the gimbal order coordinate conversion equipment that is not required.

Agreement has been reached with Apollo Spacecraft Program Office and Flight Crew Operations regarding the LEM attitude controller functional requirements. These requirements are being formally transmitted to Grumman Aircraft (GAEC) for inclusion in the controller procurement specification.

A design review of the SCS was held at GAEC during this reporting period.

Structure Subsystem

Structural analysis and layout are continuing. Design loading conditions and internal load distributions have been revised to agree with the new landing gear geometry. The method of mounting the LEM in the adapter has been agreed upon in principle and details are currently being negotiated. The determination of interaction loads between the LEM and the adapter is progressing. The vibration analysis of the CM/SM/LEM in the translunar docked configuration has been completed. The vibration analysis of the LEM in the launch vehicle is in progress.

Landing Gear Subsystem

As a result of a design study, the 160-inch cantilever gear configuration was chosen to be superior to the 180-inch tripod and the 160-inch lateral fold configurations. A large part of the detail design of this gear has been accomplished in this quarter. The design and manufacture of the 1/6 scale drop test models is progressing. The one to be used at MSC is expected to be completed in the last week of May. Analytical programs are continuing in landing dynamics, structural dynamics, structural temperatures and strength and load predictions. The importance of attaining a predictable and low descent engine crushing load for landing stability has been recognized; an analytical and experimental program with this objective has been initiated.

Environmental Control Subsystem (ECS)

Analysis, design, and drafting have continued to dominate efforts on the ECS during this report period. As a result of the optimization studies conducted, several changes to the ECS Design Control Specification LSP-330-2A are being made. The major changes are:

a. Redesigning the lithium hydroxide cartridge configuration to provide a larger cartridge for normal ECS use without excluding use of the portable life support system cartridge in an emergency.

b. Incorporation of mechanical demand pressure regulators in place of the specified solenoid actuated pulse valves.

c. Providing two small cabin fans rather than one large fan. During a majority of the mission only one fan would be required to operate.

d. Redesigning the water management section to provide three pre-pressurized tanks--one descent stage tank and two ascent stage tanks.

e. Relocation of the glycol pumps to a position upstream of the suit heat exchanger and low temperature coldplates.

Hamilton Standard Division (HSD) has thus far been unable to design a satisfactory "plate-fin" boiler for the LEM ECS without employing steam side pressure controls. The major problem is wetting the fins and not allowing liquid water to carryover into space without boiling. Consequently, HSD has recommended that all design effort on "plate-fin" boilers be suspended and that all ECS boilers be of the "porous plate" type. Action on this recommendation has been delayed pending results of some additional tests on the "plate-fin" boiler.

Grumman's specification for the Internal Environment Simulation (IES) was approved, and negotiations with the Bethlehem Corporation for its construction are under way. The IES will be used for manned testing of the ECS at Grumman.

Power Distribution.-

GAEC, Grumman Aircraft Engineering Corporation, completed the inverter study and recommended a decentralized inverter system. Full approval was not granted pending further investigation of brushless dc motors reliability. On January 29, 1964, GAEC presented four variations of their recommended inverter system. The data was not adequate for proper evaluation. GAEC was requested to submit complete data by April 21, 1964.

GAEC presented at MSC on March 19, 1964, the LEM current load and the projected load growth. On March 20, 1964, GAEC presented a two fuel cell/battery configuration based on the load analysis presented on March 19, 1964. MSC directed Grumman to design for a three-fuel-cell Power Generating Section at the 121 kilowatt hour energy level.

GAEC completed contract negotiations with Yardney Electric Corporation for an auxiliary battery. Award of contract is pending a firm battery requirement.

MSC approved the Portable Life Support System (PLSS) battery charger specification. Battery charge rate and charging time requirements were deletedfrom the specification until MSC established the firm requirements. The space suit has been redesigned for liquid cooled system, and preliminary information from Hamilton Standards indicates a 16.8 volt system may be preferred. GAEC has received and reviewed the quotes for the battery charger. A vendor selection has been made but the contract has not been awarded pending the charging rate requirement.

Fuel Cells.-

Pratt and Whitney Aircraft Corp. (P&WA) reported 100 percent completion of the LEM Fuel Cell Assembly (FCA) design and all drawings released. The FCA experimental model is scheduled for shipment to GAEC in June 1964.

The new LEM building at P&WA, South Windsor Engineering Facility (SWEF), has been completed and is now occupied. Ten Command and Service Module FCA test stands have been converted for LEM use and installed in SWEF. LEM FCA testing is to commence at SWEF in April 1964.

GAEC was directed in March 1964 to proceed with the development of a PGS comprised of three FCA's and five reactant tanks. GAEC will also initiate effort to assess the feasibility of in-flight startup of the LEM FCA's from a hot, stand-by condition. MSC will conduct a parallel effort to assess the feasibility of in-flight startup of cold FCA's.

Status of the LEM FCA Design Feasibility Tests of major items is as follows:

ITEM	SCHEDULED (HRS)	COMPLETED (HRS)
Single Cells	7432	5905
Reactant Controls	1490	375
Heat and H_2O Removal Control	700	1181
Seals	4650	3543
Heaters	270	957
ESS	390	92
FCA	217	0

Cryogenic Storage.-

Power Generation Subsystem (PGS) - Grumman Aircraft Engineering Corp. (GAEC) completed negotiations with AiResearch on the technical portion of the LEM cryogenic storage tanks contract on March 6, 1964. Negotiation on the cost portion of the contract is still under discussion on a CPIF basis; however, in an effort to prevent further schedule slippage, GAEC issued AiResearch a one month letter contract in the amount of $100,000 to initiate design work. GAEC initiated an in-house effort on preparing specifications for cryogenic components which should be completed during the second quarter of 1964.

Communications Subsystem

Pulse Code Modulation Telemetry and Timing Equipment (PCM/TE) - Radiation, Inc. has checked the CM PCM sub-modules for possible use in the LEM PCM/TE. Because of the increased environmental and accuracy requirements, the low level amplifier will be redesigned. The programmer will also require redesign because of the different sampling formats. The redesign of the programmer is about 50% complete.

Grumman has aligned requirements regarding the use of high reliability parts in the PCM system with that of Collins. The service test models will not require the use of high reliability parts. Prototype models will make use of high reliability parts not necessarily qualified but from the same batch as those parts undergoing high reliability parts qualification testing. Qualified models will use only approved high reliability parts.

Communication Subsystem Integration Contract - Negotiation was completed on the communication subsystem contract with the RCA and the contract was signed by both Grumman and RCA on February 25. An amendment to the communication subsystem specification covering weight and several small items but not affecting costs was agreed to by both parties on February 27.

LEM S-Band Equipment - S-band transponder negotiations between RCA and Motorola are in progress. Motorola is requesting increases to the specification weight and power allocations.

LEM Antenna System - The VHF lunar stay antenna test program to determine interference pattern as a function of height above a ground plane has been approved.

LEM VHF Communication Equipment - A method of evaluating zero crossing distortion associated with the use of infinitely clipped speech, has been established and work is progressing on determination of the degree of zero crossing distortion which can be tolerated. A tape recording of a standard word list is being supplied by the acoustic laboratory at Grumman. Using this recorded word list as the input, different levels of zero crossing distortion will be introduced in the system, to establish the degree of zero crossing distortion which is acceptable.

Electromagnetic and Radio Frequency Interference - A meeting was held February 5, 1964, with representation from North American Aviation (NAA), Grumman Aircraft Engineering Corporation (GAEC), the Apollo Program Office, and the Instrumentation and Electronic Systems Division. At this meeting, a decision was made to use MIL-E-6051C as a system electromagnetic interference (EMI) specification, and MIL-I-26600 and MSC-EMI-10 as a component EMI specification. It was decided that NAA, GAEC and IESD would comply with the above specifications.

Descent Propulsion Subsystem

The design control specification for all propellant and pressurization components, except the helium tanks and propellant quantity gaging, were released. The helium tank specification was delayed due to a change in helium storage pressure from 4500 to 3500 psia due to weight saving and less severe design conditions. The quantity gaging specification was delayed as a result of the decision to use passive means of propellant utilization and propellant management (PU-PM). This made the use of point sensors feasible in the system, in place of a more complex continuous quantity gaging system which was required with an active PU-PM system.

The slosh test rig is in operation at Grumman, and the plexiglas slosh tank is ready for test. The first baffle configuration to be tested is one derived from slosh analyses, and which Allison is presently designing as part of the descent propellant tank subcontract. The proposed zero-g can has been eliminated from the tank, an anti-vortex device has been added, and the tank has been lengthened two inches to accommodate the present vehicle weight and ΔV requirements. Heavyweight rig HD-1 is installed in the cold flow facility at Bethpage, and is presently undergoing checkout. Early cold flow tests on this rig will be for the purpose of verifying the passive PU-PM system approach. Rigs HD-2 and HD-3, for Rocketdyne and STL hot firing tests, have been delayed two months due to tank fabrication and system cleaning problems.

Grumman contracted to Linde for a supercritical helium storage vessel, and to AiResearch for a similar vessel and a supercritical helium fill system, as part of the supercritical helium feasibility study now being conducted by Grumman. Testing to obtain high pressure - low temperature helium PVT data is scheduled to begin prior to June 1, 1964 at Grumman.

Grumman studies of LEM vehicle stability during the landing phase have shown that the crushing of the descent engine radiation nozzle extension can cause vehicle instability under some conditions. Since the nozzle extension design is not yet well fixed, from the standpoint of materials or thicknesses required, the magnitude of the force required to crush the extension cannot be accurately determined. Since the loads on the nozzle during engine operation approach the maximum crushing load which can be tolerated, there may be a conflict between engine operating integrity and the nozzle crushing requirement. The various aspects of this problem are being investigated.

STL has activated the San Juan Capistrano, California test site, which will replace the Inglewood test site for LEM descent engine testing. Altitude test capability is expected by May 15, 1964.

The first full range (10:1 ratio) throttling test of the STL 10, 500 lb. thrust engine was made during this period. The configuration shows good combustion stability throughout the throttling range. Performance of the injector was improved during the reporting period, but is still lower than that predicted C* required to meet the specification. In addition, the injector patterns with the highest performance at maximum thrust degrade rapidly in performance during throttling. Additional modifications are being made to improve both maximum thrust performance and throttling characteristics. Other problems encountered with the injector were poor distribution of the fuel flow in the injector, which has been improved by design modifications, and burning of the injector pintle tip, which has been changed to a stainless steel clad copper design to provide both high thermal conductivity and oxidation resistance of the tip.

The first ablative throat inserts were fired by STL and showed high localized ablation. This was attributed partially to the fuel distribution problem. As a result of this problem and the low injector performance, a full ablative chamber has not been fired. In the event that the full ablative chamber is not satisfactory, STL is pursuing a limited backup effort using a JTA graphite insert.
STL has decided to design the radiation nozzle extension using Haynes 25 material, based on the poor creep buckling characteristics of 6AL4V titanium and the long lead time associated with a columbium design. The columbium is still being investigated. The use of flexures for gimballing the engine has been abandoned due to the force requirements, and the present design uses gimbal bearings.

The Rocketdyne prototype engine design was released during this reporting period. This engine is 75 pounds overweight, and a weight reduction program is being implemented by Rocketdyne in order to meet the specification weight. The radiation nozzle extension for this engine is 0.040 inch thick L605 material, a cobalt base material similar to Haynes 25. An injector pattern has not been finally selected, but has been narrowed to two patterns, a film cooled triplet and a mixed (both like impinging and unlike impinging) doublet. Both patterns meet the Rocketdyne predicted C* requirement at maximum thrust.

Helium injection tests on plexiglas models have revealed a problem in the distribution of helium to the injector orifices during the helium injection phase of engine operation. No detrimental effects on engine operation have been noted, but improved helium distribution schemes are being investigated. Injector "popping" or pressure spikes, is a problem observed on most injector patterns. On stable configurations, no detrimental effects are noted, though pressure peaks are as high as 400 psi above normal chamber pressure. The pressure rise and damping is similar to that experienced during bomb stability tests of the same injectors.

Some streaking of the ablative chamber wall has been noted on most tests at Rocketdyne. The severity of the streaks appears to be a function of the particular injector. In the manufacturing cycle, a significant quality control problem exists in the tape wrapping of the chambers. A more stringent process specification and better developed techniques are required to insure a consistent high quality of ablative chambers. Rocketdyne is pursuing the use of throat inserts, of precharred materials, as a backup effort if needed.

Ascent Propulsion Subsystem

Grumman has started testing with the slosh rig at their Bethpage facility. This rig will evaluate various baffle configurations for both ascent and descent propellant tanks.

Grumman has released the design control specifications for all propellant and pressurization system components, except the helium tanks and propellant quantity gaging. The helium tank specification was delayed due to a change in helium storage pressure from 4500 to 3500 psia which results in a weight saving and less severe design conditions.

An in-house study has been completed for predicting the present ascent engine performance and what performance can be realized due to changes in chamber pressure, C-star efficiency and hard and soft throats. The in-house study predicts a performance drop of 6 seconds from the specification value using the present engine design. This study also shows that the specification value can be attained by increasing the chamber pressure to 120 psia, increasing C-star efficiency to .973 and incorporating a hard throat. This plan has been implemented by Bell.

Bell has conducted engine stability tests with the chamber pressure reduced to 55 psia (normal is 100 psia). Low frequency instability occurred but was not of such a magnitude as to terminate the test. There was no engine damage as a result of this off mode running condition. Additional tests were run at a chamber pressure of 70 psia. No instability occurred during 10 runs of 5 seconds duration each. Bomb tests were conducted using black powder which resulted in pressure spikes of 30% or less. This procedure is inadequate and Grumman is currently preparing criteria to attain higher pressure spikes by using high explosive charges.

Grumman has completed negotiations with Bell for the all ablative engine weight. The negotiated weight is 196.0 lbs. which is an 18% increase over the radiation cooled nozzle extension design weight.

The injector fabrication problems have been resolved during this period. The fabrication time cycle has been reduced from 12 to 6 weeks and reworks are now at a minimum. Injector performance on all tests showed good consistency and reasonably good performance. The major problem attributed to the injector is "undercutting" of the ablative thrust chamber. This "undercutting" problem appears to be the result of pressure differences between the core and the barrier flows which initiates a vortexing of gases that gouges out the ablative material adjacent to the injector. An injector is being designed that is similar to the 3K injectors used in the earlier part of this program. These 3K injectors experienced no "undercutting" and showed good performance. There were more barrier holes with smaller diameters than the present injector designs which at that time attributed to the fabrication problems. Full duration firings on current chambers require a 4-inch long water cooled section adjacent to the injector to prevent thrust chamber failure due to the "undercutting".

The Phase "A" thrust chamber screening program has been completed. AVCO, HITCO and TAPCO thrust chambers and barrel sections were evaluated during this period. The results of this testing showed that all three manufacturers' chambers were comparable and that all three would be included in the Phase "B" thrust chamber screening program. The first Phase "B" thrust chambers with expansion ratios of 40:1 will be tested at AEDC in May 1964. Thrust chambers with both "hard" and "soft" throats will be included in the Phase "B" evaluation.

Reaction Control Subsystem

The primary efforts during the past quarter have involved completion of the procurement specifications for the subsystem components, the operation of the HR-1 blowdown test rig and the completion of the construction of the cold flow test rig (HR-2). In addition, analytical and experimental investigations concerning the thermal problems associated with the Reaction Control Subsystem (RCS) clusters have been completed and the results have been presented to the Manned Spacecraft Center (MSC).

The common usage/common technology components procurement specifications have been completed but are being revised in order to comply with the MSC requirement - that of identification and justification of the specification differences between Grumman Aircraft Engineering Corporation (GAEC) and North American Aviation (NAA) requirements. The procurement action such as the release of the Invitations to Quote (ITQ) and the purchase orders has repeatedly slipped from the predicted schedule due to GAEC's underestimating of the time for the preparation and processing of the procurement paper work. During the reporting period 50 percent of the ITQ's have been released. The delays in the specification release and the associated procurement action have not jeopardized the subsystem qualification schedule mainly because the over-all Lunar Excursion Module (LEM) development and flight schedule has been changed during the past reporting period.

The testing of the helium pressurization system components on the HR-1 rig has been initiated during the reporting period and the testing is approximately 70 percent complete.

The build up of the HR-2 rig has been completed and the instrumentation checkout initiated.

Plans for the next quarter include completion of the procurement action on all RCS components, completion of cold flow testing on HR-2 with one-half of the subsystem (eight thrusters), and initiation of the system checkout on HR-3 - the subsystem development rig at Marquardt Corporation. In addition, an updated RCS development plan and PERT logic will be finalized during the next quarter.

Pyrotechnics

Ascent-descent stage separation - The system has been defined as a four point system using bolts which have both an internal explosive charge and an explosive nut. The interconnect and firing systems have not yet been defined; both an electric initiator for each of the eight charges and a manifolded confined detonating fuze (CDF) system are being considered. The former offers advantages in checkout and minimum explosives while the latter appears desirable from an installation viewpoint.

Propellant Dispersal System - Because of the relatively small amount of propellant involved the Missile Test Office Range Safety (MTORS) at the Atlantic Missile Range has accepted the MSC position that a system is not required for the ascent stage. The requirement on the descent stage is being negotiated. If one is required it probably will be similar to that for the service module, using identical shaped charges mounted on the adapter and interconnected to function with the service module system. NAA will be assigned the responsibility for the system.

Landing gear uplock - Both linear shaped charges and other devices are being studied to release the landing gear to its deployed position.

Ascent-descent stage umbilical separation - Linear shaped charges, guillotines and other devices are being considered. Both electrical and hard lines must be severed and some of the latter, particularly cryogenic lines, must be reliably sealed. This function may well be the most difficult to accomplish reliably and safely.

Explosive valves - Pressurization and cross-feed propellant valves will be required. It may be possible to use the NAA pressurization valve, but the propellant valve does not appear compatible with LEM requirements.

Landing aids - GAEC is considering the use of vehicular mounted flares and pyrotechnically deployed penetrometers. No firm requirements have been established to date.

Antenna deployment release - The same concepts as for the landing gear uplock are being considered for this function.

Operational Instrumentation Subsystem

An evaluation of sensor and transducer requirements has been completed. As a result of this analysis, it has been possible to determine the types that will be required for adequate monitoring. Procurement specifications are in preparation for seven types; namely, vibration, linear acceleration, pressure, displacement, temperature, acoustics and heat flux. In support of this effort, additional studies have been initiated to optimize the selection by an evaluation of tradeoffs involved in factors of weight, size and reliability.

Signal Conditioner requirements have been determined with the following types deemed as sufficient. DC amplifiers, frequency to DC convertors, resistance to DC Convertors, passive attenuators and DC power supplies. Procurement specifications are being prepared.

Requirements for the onboard checkout electronics assembly are being prepared based on subsystem needs.

The procurement specification for Caution and Warning Electronic Assembly (CWEA) has been completed and is currently undergoing review prior to formal approval.

Formal efforts on Data Storage Equipment have ceased pending the outcome of the methods of data handling study now in process by NASA-ASPO. Commercial capabilities for anticipated voice and digital requirements have been surveyed and specifications compiled for future use.

The scheduling of each component area has been reviewed and new Test Logic Charts compiled to reflect the latest vehicle utilization listing.

Television Subsystem

A set of specifications for the LEM television camera was prepared and submitted along with a purchase request to Procurement. Procurement action including preparation of the Procurement Plan and the RFP was initiated.

A study of the test equipment required to test and evaluate the LEM TV camera was completed. This study included determination of the most optimum scan conversion technique for use with the LEM Slow-Scan Television System. Procurement of the required equipment was initiated.

Procurement specifications for the cable linking the television camera with the LEM wereprepared and released.

Procurement of the LEM television camera is now pending release of a request for proposal (RFP).

The LEM prime contractor, Grumman Aircraft and Engineering Corporation (GAEC) is in the process of procuring an 80 ft cable which will link the television camera and the LEM. Test and evaluation of this prototype cable will be undertaken during the next quarter.

Radar Subsystem

1. The RCA weight and power trade-off study was submitted on Feb. 19, 1964, for review by Grumman Aircraft Engineering Corporation (GAEC) and MSC. The report suggested that the accuracy and range requirements be relaxed to

reduce the weight and power of the radar systems (landing and rendezvous radars).

2. The landing radar contract was signed on March 16, 1964, with Ryan.

3. The RCA quarterly report was submitted on March 19, 1964.

4. Tentative approval has been given for the LEM radar performance specifications (GAEC LSP-3702A).

The landing radar specifications are not firm. The Flight Crew Support Division (FCSD) of MSC has requested that the accuracy and altitude requirements be extended to determine orbit circularization. The RCA weight and power trade-off study recommended the reverse procedure to reduce the weight and power requirements and ease the design.

The rendezvous radar specifications are not firm. RCA has recommended the elimination of surface tracking and Grumman Aircraft Engineering Corp. (GAEC) has recommended that the requirement for tracking a beacon on the lunar surface be eliminated. MSC has indicated that the rendezvous radar be used to track either a corner reflector or beacon on the lunar surface. This requirement complicates the antenna servo design.

The thermal problems caused by the RCS engines on the rendezvous radar and the lunar surface on the landing radar have resulted in a redesign of the preliminary packaging concepts for the antenna and associated electronics. It was intended to use the antenna as a thermal radiator; however, the heat from the RCS engines has required that the antenna electronics assembly be moved away from the antenna and additional cooling be employed.

Instrumentation/Communication R and D Subsystem

The following vehicles have been tentatively scheduled for IESD Government furnished equipment (GFE) instrumentation/communication R and D deliveries to Grumman Aircraft Engineering Corporation (GAEC).

Vehicle	Delivery Schedule to NAA
LEM 1	December 15, 1965
LEM 2	March 15, 1966
LEM 3	May 15, 1966
LTA 1	September 15, 1965
LTA 4	November 15, 1965
LTA 7	February 15, 1966
LTA 8	January 15, 1966

To date, no official program direction has been received from ASPO. Consequently, all effort has been expended toward establishing a realistic program for delivery of GFE to GAEC. It is expected that a Measurement List for LEM 1 and LTA's 1 and 4 will be released prior to June 1964.

During December 1963, GAEC-ASPO-IESD negotiated a firm Measurement List for LEM 1. Subsequently, this program was cancelled. In the interest of the over-all program, IESD has continued the procurement of evaluation hardware in order to select qualified components for other LEM vehicles.

Investigations at GAEC by IESD revealed potential problem areas for R and D antennas on flight vehicles. Telemetry and command antennas require analysis regarding methods of radio frequency transmission from the LEM while the latter vehicle is enclosed by the adapter during launch configuration. A second potential problem in the above configuration also involves the possibility of antenna mismatching due to the proximity of the adapter to the LEM. Ground radar could trigger the beacons on the pad and cause failure due to the mismatch. IESD is assisting GAEC in the resolution of these problems.

Scientific Equipment

The total Apollo spacecraft weight allocated to scientific equipment is 250 pounds. The exact location of scientific equipment for various missions cannot yet be specified; therefore each module is being designed to meet the following capabilities for any mission phase prior to abandonment:

Command Module	80 pounds 2 cubic feet
LEM (ascent stage)	80 pounds 2 cubic feet
LEM (descent stage)	210 pounds 9 cubic feet

It is probable that additional volume will be available in the LEM descent stage; additional volume may also be obtained after jettison of certain spacecraft expendables.

SPACE SUIT ASSEMBLY

Space Suit

One prototype A-3H-024 Apollo space suit was delivered in March 1964. The following evaluation tests have been conducted at MSC, Hamilton Standard (HS), North American Aviation (NAA), Grumman Aircraft Engineering Corporation (GAEC), and Massachusetts Institute of Technology (MIT).

A. Mobility

1. Reach tests (at MSC)
2. CM and LEM mock-up tests (at NAA and GAEC)
3. Tests of integration of portable life support system (PLSS) with suit (at MSC)

4. Guidance and navigation (G&N) compatibility tests (at MIT)

B. Comfort evaluation in conjunction with mobility tests

C. Vision

1. Visual field tests (at MSC)

2. Visibility in mock-ups (at MSC, NAA, GAEC, and MIT)

As a result of the above evaluations, in-house studies, and contractor studies, the following are some of the changes and improvements to be incorporated into future Apollo suits:

1. The helmet assembly has been changed to provide for additional visual field capability. Improved downward visibility is required to adequately see the CM display panel and suit disconnect fittings.

2. The helmet assembly suspension system has been changed so as to provide better adjustability for comfort and fit.

3. The provisions for vomitus removal have been deleted. The feeding port assembly has been redesigned and will provide for simpler feeding operations by use of less mechanical parts.

4. The waste management system is being studied and designed to give better comfort and to insure compatibility with spacecraft systems.

5. The suits will use suit-mounted gas disconnects. Testing indicated that suit umbilicals with in-line disconnects at the end of them were unacceptable because of their bulkiness and interference with suit operations.

6. Provisions for secondary protection layers in the suit to act as "backup" to the primary suit pressure/load carrying layers have been eliminated. These provisions have been deleted because of the compromise they impose on suit mobility, comfort,

weight, and donning. During lunar operations the primary suit layers will be protected by the thermal coverall and meteoroid protection features.

7. The basic construction of the suit and suit fittings will be redesigned to be more resistant to wear-and-tear. Testing has revealed a number of minor design deficiencies.

An Apollo Space Suit Assembly Performance Specification is in preparation. This specification will be in much more detail than the ASPO Suit Specification, and will be used as the prime means of defining the technical requirements of the space suit to the Apollo suit contractor. The Specification is scheduled for final completion and release in June 1964. This Specification, a Program Plan, and a General Statement of Work will form the "procurement package" with which negotiations with HSD will be initiated for a multi-year Apollo Space Suit Development Program. The target date for contract award of this program is November 1, 1964. Existing contract provisions will cover effort until the new contract is put into effect.

Procurement action has been initiated on a number of development programs. These programs include the following:

(1) Meteoroid garment development

(2) New upper arm joint development

(3) Suit sizing

(4) New helmet development

(5) Updating and delivery of suit drawings

(6) Liquid cooled system study, materials investigations, and improved controls and displays development.

Portable Life Support System

The portable life support system development is being revised to incorporate the liquid transport thermal control concept. Sizing and optimization of the internal liquid garment is under way. One prototype garment has been fabricated and successfully man tested. An optimized second garment has been fabricated based upon the initial tests and follow on manned testing will begin shortly. As a parallel effort, preliminary layout and configuring of the portable life support system itself is nearing completion. Spacecraft modification to accept the new system will be minimal.

A new harnessing approach which relies upon hard straps in certain areas in lieu of soft belts is under investigation. The concept promises to make the task of self donning the portable life support system easier.

The emergency oxygen supply system has been optimized and redesigned to reduce weight and volume. The weight has been reduced by over two pounds. The first mockup of the system has been delivered and is under evaluation.

Delivery of the first thermal protective coverall garment has been made. Evaluation testing of this unit will be limited.

SPACECRAFT SYSTEMS ENGINEERING

FLIGHT TECHNOLOGY

Aerodynamics

During February, it was decided that the tower flap Launch Escape System design should be discontinued in favor of the canard system design. The canards consist of deployable portions of the LEV ballast compartment fairing. The deployed fairings act as lifting surfaces which destabilize the Launch Escape Vehicle and cause it to reorient in the heat shield forward position. The reasons for selecting the canard system over the tower flap system were greatly improved dynamic stability characteristics of the LEV, improved apex cover jettisoning characteristics, and more favorable main chute deployment attitude during low altitude aborts. NAA is proceeding with the mechanical design of the canard hardware and the implementation of a wind tunnel program to complete the definition of the canard characteristics. The first canard hardware is expected to be available the last quarter of 1964.

The "boost protective cover concept" has been adopted. The cover consists of a protective layer of material over the conical surface of the Command Module which remains permanently attached to the launch escape tower. This cover is jettisoned during normal missions along with the launch escape tower. The purpose of the boost cover is explained in greater detail in the section on ablation material thermal performance below. Both rigid and non-rigid cover designs have been investigated. The current design approach is the non-rigid design.

The following wind tunnel test programs have been completed during this quarter:

a. FS-3 - Alpha-beta tests of the tower flap configuration at supersonic speeds at AEDC.

b. FS-10 - Tower-apex cover separation tests at subsonic speeds in the North American TWT.

c. FSJ-3 - Jet effects tests on the stability of the launch escape vehicle at supersonic speeds, at AEDC.

d. HL-1C - Heat transfer on the Saturn V launch payload configuration at supersonic speeds at Langley Research Center Unitary tunnel.

Ablation Material Thermal Performance

Preliminary studies have been completed at MSC of methods of reducing the ablation material weight on future spacecraft Command Modules. Studies included the addition of a "boost protective cover", increase in the allowable bondline temperature at landing, and reduction in reentry performance requirements.

The "boost protective cover concept" consists of a protective layer of material over the conical surface of the Command Module which is jettisoned after the atmospheric phase of the launch trajectory. The cover provides the necessary boost heating protection so that the ablator on the Command Module provided for this protection is no longer required. In addition, the cover can protect a thermal control coating on the outer surface of the ablator. The thermal control coating, in turn, will reduce the maximum temperature of the ablator during space flight from 250° to approximately 100°F. The reduced initial temperature at reentry provided by the thermal coating will, in turn, permit reduced ablator thickness for a given total heat load during reentry. The reduced ablation temperature will also reduce the heat leak to the Command Module Environmental Control System, thereby saving weight in that system also.

The increase in the allowable bondline temperature at landing is being investigated further. It is estimated that an increase to 800°F allowable temperature on the blunt face will save over a hundred pounds in ablator weight.

The reduction in reentry performance being considered is a reduced entry range from 5,000 nm to 3,000 nm. Further study will be required to determine whether the potential weight saving is sufficient to justify the reduction and operational flexibility.

Heat Transfer

Testing has recently been completed at Langley on a temperature sensitive paint heat transfer model. The purpose of these tests was to define in greater detail the heat transfer characteristics in and around holes and protuberances on the Command Module. Data are now being analyzed. No information is yet available on how the results compare to the current heat shield design values.

Natural Environment

A parametric investigation of the micrometeoroid protection requirements for Apollo has just been completed by NAA. The purpose of the study was to identify the additional weight required on the spacecraft to provide a given probability of not aborting the mission due to meteoroid puncture. The analysis included the present Command and Service Module structural configurations as well as the present configurations with the addition of an external meteoroid bumper. Optimum protected weight distributions were computed including the LEM ascent and descent stages. These studies are now being used to define meteoroid protection design criteria.

The contract between NAA and GMC for experimental simulation of meteoroid impact has been approved. Testing of the penetration characteristics of samples of the Apollo structural material will begin in the second quarter.

SYSTEMS INTEGRATION

ASPO-PE6 has completed plans for an "Electrical Power Control Program" to maintain control of energy growth for Apollo CSM and LEM. Salient features of the program are:

a. Establishment of a control energy level within the capabilities of the electrical power system, on which electrical energy is to be apportioned to subsystems for Normal and Emergency modes of operation.

b. A reapportionment procedure by which subsystems request changes in energy from the Electrical Power System Group. Requests are to be investigated to determine the impact on the electrical system. Final resolutions of problems concerning reapportionment will be made by prime contractor management, or ASPO.

c. Periodic monitoring of subsystem energy and power requirements in order to maintain control of energy growth.

d. Periodic reports of subsystem energy and power status.

MSC-ASPO has established ground rules for selection of spacecraft electrical wiring insulation for use on the Apollo Spacecraft, and has directed NAA, GAEC and MIT accordingly. The ground rules basically require the use of "Teflon" wiring insulation, or wiring insulation that can be established by actual test data to perform equal to, or better than "Teflon", in both the pressurized cabin, and outside the pressurized cabin. Any approved spacecraft wiring is permitted within potted or hermetically sealed enclosures.

ASPO-PE6 has completed a coordinated review of the following Criteria or Standards: "Electrical/Electronic Assemblies: Overvoltage or Reverse Polarity Damage"; "Protection of Exposed Electrical Circuits"; "Wiring Insulation: Flammability and Toxicity"; "Protection of Electrical/Electronic Assemblies from Moisture Damage" and Electrical Connectors - Keying." Recommended changes, additions, and corrections have been forwarded to the MSC Manned Spacecraft Criteria Board.

ASPO-PE6 made arrangements for representatives from GAEC and NAA to visit Sandia Base to gain first hand knowledge of development of high reliability connectors. Both GAEC and NAA were enthusiastic concerning the value of the information gained during the visit.

A Guidance & Navigation Subsystem/Acceptance Checkout Equipment-Spacecraft (ACE-S/C) interface problem, unresolved for several months, was resolved by 1) lowering of output impedances within the G&N subsystem, and 2) provisioning of line drivers on noise and phase critical lines, and by modifying ACE-S/C carry-on equipment to provide more optimized input impedances.

NAA has received direction to eliminate all In-Flight Maintenance (IFM) on CM electronics packages. This direction is for both Block I and Block II equipments. NAA is expected to complete their in-house Vertical Cold Plate Study within the next 2-3 weeks. This study is meant to determine the cost, schedule impact, and engineering feasibility of implementing the Vertical Cold Plate on the Block II CSM.

A meeting was held at GAEC on April 9 and 10, 1964, between GAEC, NAA and ASPO personnel in order to discuss integrated drawing systems of both contractors, determine possible areas of merging their approaches and internally exchange ideas. As a result of this meeting, both contractors are considering changes in order to more closely align their methods

A meeting is tentatively set for April 22, 1964, to discuss the requirement and optimum configuration for the LEM On-Board Checkout Equipment (OBCE). This meeting will be between GAEC, MIT and MSC personnel. NAA will be invited to attend also.

NAA has been advised to implement a block concept for R&D instrumentation on CSM 011, 012, 014, 015. These vehicles will carry identical sensors but actual selection will depend on flight objectives.

A revised procedure negotiating measurements lists is being sent to the contractors which will allow a quicker response to measurement and instrumentation changes by MSC.

A document entitled "Evaluation of System Considerations for LEM Backup Guidance" was written by ASPO. The report enumerates all proposed ground rules for the LEM abort Guidance System and the reasons for their selection or rejection. The document also discusses two ground rule modifications and the effect of the modifications on system mechanization.

GAEC has been requested to study the capability of the LEM Stabilization and Control Subsystems to stabilize the command and service modules in in lunar orbit during fine alignment of the LEM Inertial Measurement Unit. This capability is required for an unmanned mission. GAEC now schedules completion of the study in April, 1964.

An ASPO investigation of the coordinate Transformation requirements for the LEM attitude display found that the complex device proposed by GAEC cannot be significantly simplified. The device may be eliminated, however, by the use of a shelf mounted display (viewed downward), but pilot aversion to such a display must be overcome. GAEC is continuing with the incorporation of the transformation device and with simulations evaluating the shelf mounted display.

The method of landing site selection control is an unresolved functional interface between GAEC and MIT/IL. Study is continuing by both parties and resolution is expected in April, 1964.

NAA has been directed to prepare and maintain Interface Control Documents concerned with the spacecraft-SIVB interface. Preliminary ICD's have been completed by NAA.

A draft functional and performance specification for the Command Module SCS has been completed by ASPO.

MIT was given configuration definition for Block II G&N Systems by the Manager Guidance and Navigation the last week of 1963.

GAEC was directed to use a strapped down inertial reference to meet the abort guidance system requirements for LEM.

A work statement for a strapped down technology development program at MIT was prepared and a estimate received from MIT for the first years effort ($1.9 million including a great deal of one-time test equipment costs).

MIT submitted a proposal for the first year's effort on strapped down technology development. This will be reviewed and a final work statement written during the fourth quarter of FY 64. The effort funded will be reported herein at that time.

A survey of the four recognized organizations currently developing high accuracy strapped down guidance systems was made. The results of their development programs including substantial testing under dynamic conditions indicate that a system with a drift rate of 1 deg/hour can be readily achieved and that such drift rate may approach 0.1 deg/hour by the time of LEM operation flights.

GAEC has investigated the following abort guidance schemes:

a. Q guidance

b. Thrust-Velocity Guidance

c. T_i Compensation guidance

d. T_t Guidance

e. Open loop or no compensation

The guidance schemes a-e cover a varied spectrum of complexity, decreasing in complexity as they are listed.

The Q guidance can handle extremely for off nominal conditions and maintain a clear pericynthion on the first burn under the conditions previously stated, whereas, the open loop scheme would have to give up the clear pericynthion concept on the first burn if the initial condition errors are much greater than those listed. The open loop scheme could handle the thrust uncertainties by flight path angle biasing; however, the initial condition errors could create a situation in which a 100 fps overspeed would not yield clear pericynthion.

The guidance scheme greatly affects the mission operations and also the hardware complexity and weight.

A review was held between MSC (ASPO and GCD) and GAEC on the accuracy requirements and the guidance concept to be mechanized for the LEM abort guidance system. GAEC stated that under the following conditions a clear pericynthion could be achieved with a single burn and rendezvous completed within the LEM ΔV budget:

Burnout	- 50,000 feet
Velocity	- Circular + 100 fps
Drift rate	- $2\frac{1}{2}$ deg/hour
Initial Alinement	- 0.2 deg
3 Thrust Errors	- 4% (Thrust compensation provided in mechanization)
Initial errors	- 10 meru drift for 390 seconds altitude = 2,000 ft. altitude rate = 4 fps

GAEC Abort Guidance System studies have shown that a clear pericynthion of 30,000 feet can be achieved at the end of first burn with an overspeed of 100 fps greater than circular velocity at 50,000. This is based on a strapped-down attitude reference system with a 3 σ drift rate of 2.5 deg/hour and a pitch programmer using T_1 Guidance Compensation. The T_1 Guidance scheme can handle initial vertical velocity errors as large as 84 fps. This is equivalent to an allowable powered descent drift rate of 19 deg/hour. The mechanization for T_1 compensation will weigh from 6 to 12 pounds. The primary disadvantage of T_1 compensation is that it does not allow the descent and ascent stages to be used in combination. The ground rule that GAEC is using to design the pitch programmer is to use the descent engine when it can complete the abort. If the descent engine cannot complete the abort, it is staged and the ascent engine is used. It is possible, however, to use the descent stage for the vertical rise phase with T_1 compensation.

It was determined that only 1 additional signal would be required to guide the S II as well as the S IVB with the Apollo G&N during launch into earth orbit and that this interface will be implemented.

The mechanization of the Apollo S IVB spacecraft guidance and control interface is being implemented in accordance with CCA 74.

Requirements for G&N - S IVB interfaces and G&N - SCS interfaces for the following signals were reviewed in NASA Coordination Meeting 14A at MIT:

a. Saturn Thrust Monitor
b. Lift Off
c. Thrust enable
d. G&N Monitor; Altitude Control, ΔV, and Entry Modes
e. Abort
f. Separation
g. 0.05 Backup Switch and 0.05 G Command
h. Thrust on-off Command (Saturn Backup)
i. Signal Carrier

A failure indicator signal initiated by the S IVB-IV platform has been added to the interface mechanization of the S IVB-IV to CSM G&C.

Venting

It will be necessary for the S IVB to vent after translunar injection and prior to docking. MSFC stated that the magnitude of the vent is Unpredictable and could be as large as 30 fps and requested that a study to determine what portion if any of this ΔV could be tolerated along the velocity vector to assist them in the design of the venting mechanism. MIT/IL has investigated the effects of the unpredictable vent on midcourse velocity correction. The study showed that for venting normal to the translunar trajectory the midcourse velocity corrections required are an order of magnitude smaller than for venting along the velocity vector.

MSFC was requested to vent normal to the outbound translunar trajectory plane since midcourse ΔV requirements are minimized in that direction. MSFC stated that this was a problem unless another result system was added to the current longitudinal vent mechanization that is required for earth orbital venting. At present the vehicle must yaw 90 degrees to vent normal to the plane which would cause the S IVB platform to go into gimbal lock. The reaction control propellant required to perform this manuever has not been provided by MSFC.

MSFC is considering a continuous vent in earth orbit of 1.6×10^{-5} g's. MIT/IL is investigating the problem this causes in performing onboard orbit determination.

The Block I computer programming activity and requirements have been formulated by MIT. The following is a list of the programs that are required for Block I.

a. Computer FTM Program - Computer Subsystem Checkout ropes

b. Greasy - Compilation of special programs which has the sole functions of greasing the ways for program module construction and release procedures.

c. Eclipse - This includes programming, CDU driving, self and interface test (5500 words).

d. Sunrise - This includes programming, IMU modes, guidance laws, self test (9790 words).

The Prelaunch rope program was received from Raythron and has been used in a simulation with the IMU, AGC and CDU's for platform vertical erection and gyro compassing.

MIT/IL has developed AGC program for abort from translunar flight. The abort computer program will compute derived landing site, minimum time, and fuel critical abort trajectories. The computations will be executed on board the CSM.

The MIT Apollo orbital navigation program was put in AGC lanquage and checked out on the M14-800 simulator. Good accuracy correlation was obtained when checked against a standard navigation program.

A study was performed by MIT/IL in order to determine the reentry flight path angle uncertainty and touchdown errors that would be expected for unmanned supercircular reentries. The flight profiles studied are being considered for the heat shield qualification tests.

Guidance and Navigation system error sources and various mission profiles were considered in computing uncertainties for all inertial, inertial plus position and velocity update, and inertial with realignment and position and velocity update.

Based upon a quick look into the feasibility of performing an unmanned earth orbit mission without the G&N system, it was concluded that the SCS could be used as an attitude reference for one or two orbits and have accuracies at retro suitable for recovery. The number of orbits is dependent upon the number of maneuvers performed since the drift rate of the BMAG's is 1.5 deg/hour in attitude hold mode and 7.0 deg/hour in a torqued mode. It is possible to add horizon maneuvers and gyro compassing to increase the stay time.

G&N Gyro Drift Requirements

A preliminary investigation was made to determine if a gyro with a null bias drift of 20 meru would be suitable for the Apollo mission requirements. The current gyro specification has a 10 meru null bias drift with a stability of 5 meru. The investigation indicated that in order to meet the 0.5 nmi lunar landing CEP, and a reentry accuracy of 10 nmi (3σ), it would be desirable to compensate for the null bias drift for a 10 meru gyro and compensation would be required for a 20 meru gyro. The null bias drift during the powered lunar landing or atmospheric reentry is not the critical error. The predominant error is due to the drift that occurs from the last time the IMU is aligned. Error caused by the g sensitive drift or mass unbalance of 20 meru/g do not have an appreciable effect on the lunar landing accuracy or the reentry accuracy The drift of 20 meru/g does, however, have an appreciable effect on the accuracy for launch into earth orbit. The error caused by the g sensitive term could cause the earth orbit insertion to be poor enough so that the ability to perform a suitable translunar trajectory would not exist. A study is being performed in order to obtain more detailed trade-off results.

A GAEC/MIT Coordination Meeting was held on 25 - 26 February. The objective was to establish a jointly agreed upon list of functional interfaces and obtain a definition of each of them. The discussions were based on a ground rule of manned vehicles only, requirements peculiar to unmanned vehicles will be discussed at a later date. Another ground rule used for the meeting was that full throttle authority existed even though GAEC has taken exception to NASA direction and recommends limited authority.

Sixty-five functional interfaces were discussed. Fifty-five were agreed to. General definitions were agreed upon for forty-two of these. Four were deleted. Six require further engineering meetings, and these are being scheduled during the next few weeks. Definitions for the balance will be written and reviewed at another coordination meeting in approximately four weeks.

Many of the ICD's have been prepared by GAEC and sent to MIT for review and signature. Most of them are being reviewed because of the change to a strapped down attitude reference assembly.

A review of the guidance and navigation requirements for CSM retrieval of LEM was made. The radar performance requirements derived by NAA were less stringent in all cases than the GAEC specification.

MIT studied the use of only range rate or range with angle tracking. A saving in midcourse ΔV using range rate in the order of 5 fps was arrived at when compared to similar operations using range data.

The subsystem managers package for E&D for the rendezvous and landing radars was prepared and approved.

RCA presented the results of tradeoff studies on the rendezvous and landing radars to GAEC. MSC attended. A series of engineering evaluations by MIT, GAEC, and MSC during the past few months have shown that the requirements established for these radars in the original specification exceeded the requirements in some areas. GAEC has analyzed the tradeoff versus the currently established requirements.

The use of landing radar for descent and ascent monitoring, orbital insertion, and orbit circularization was studied. As a result it was learned that the accuracy requirements for circularization can be reduced to 0.3% (3 sigma) for slowly varying errors affecting total velocity. For cutoff, the revised requirement for total velocity is 0.5% (3 sigma). A set of accuracy requirements was agreed to and signed off by FCSD and ASPO. A weight analysis was made on the basis of comparing landing radar and abort programmer weights only, e.g. FCSD abort scheme versus GAEC landing radar and abort scheme. This weight analysis was signed off by ASPO, FCSD, E&D-G&CD, and IESD.

A contract change authorization was issued to GAEC for the following studies:

a. A detailed study by Ryan of the accuracy attainable in the type landing radar they have contracted for.

b. A detailed study by RCA of the ability of the rendezvous radar to accomplish these tasks.

c. A follow on study by GAEC to evaluate all system aspects of this monitoring and abort guidance scheme.

Ryan was requested to make a preliminary study and to present the results at GAEC on 26 February. This preliminary study was limited in scope:

a. Only a few days effort.

b. Temperature effects not fully explored.

c. Lunar bias variations not fully explored.

d. Effects of vibration on ascent not explored. (This affects ability to measure total velocity for cutoff with high accuracy - the alternate of course is to use the X axis accelerometer for cutoff).

The preliminary study results show that the accuracy requirements probably can be met. Ryan has stated that a more thorough evaluation is necessary before they would be willing to contract for a higher accuracy radar.

The landing radar can be used for abort within the current LEM fuel budget if the radar accuracy requirements are met. If the accuracy requirements are not met additional fuel would be required (dependent upon specific accuracy met), but not necessarily above the current fuel budget. (additional studies are required). Studies have been started in E&D-G&CD, and ASPO to fully explore all systems aspects of such a change. The G&CD studies will be complete approximately April 1, 1964. The Ryan and RCA detailed studies will be complete approximately April 23. GAEC detailed studies should be complete a few weeks later.

A series of engineering meetings between MIT and NAA, NAA and GAEC, and MIT and GAEC indicate that common usage of the rendezvous radar/transponder for LEM and CSM applications is feasible. The major problem area is associated with the antenna pedestal, gimbal, and gimbal servo design. To provide a capability to land to a lunar surface beacon the gimbals vehicle engine cutoff technique. MSFC maintained its previous position that the EDS engine cutoff circuitry for the launch vehicle will be a "cold-wire" design. The MSC contended that "hot-wire" circuitry must be provided to ensure thrust termination for any eventuality of an abort. The EDS specification is being revised to incorporate requirements and decisions that were established during the panel meeting and will be submitted for immediate design implementation by the contractors.

DESIGN INTEGRATION

Service Propulsion System

NAA was notified that the Service Propulsion System and the Lunar Excursion Module (LEM) Ascent and Descent Systems are to be loaded with an accuracy of ± .25%. This loading tolerance applies to loads from 1,000 pounds to full tank capacity. No requirements have been set for loads less than 1,000 pounds.

Docking Interface

Effects of Docking Requirements on LEM Configuration - GAEC was requested to investigate the effect of docking requirements on the LEM configuration. Prior studies have indicated that the forward docking tunnel provides the most attractive means of provisioning the LEM with its required docking capability. As the LEM design has progressed, there have been changes to the cabin configuration and crew restraint systems as well as the selection of the docking system concept. Any or all of these factors could invalidate the results of previous studies. GAEC is expected to report their results to MSC by the first of May 1964.

<u>Crew Transfer</u>.- During this quarter, NAA has satisfactorily demonstrated crew transfer feasibility with the probe and drogue docking

concept. Tests were conducted using a tunnel configuration which represented the present 29 inch diameter tunnel with the minimum revisions to incorporate the docking subsystem as well as with a NAA proposed 31-inch diameter tunnel, which was also about 12 inches shorter. (The latter tunnel has been proposed by NAA as one of the items being considered for "Block II" changes) Test results indicate that crew transfer can be accomplished through the 29-inch diameter tunnel.

These tests were accomplished using an air bearing mounted mockup with the test subject suspended and counterbalanced from overhead. The net result is a limited simulation of "zero g" conditions. Apollo prototype and development space suits were used in the testing.

Weights

Table I shows the Control, Target and Current Status Weights and changes from previously reported data. The most significant reductions are in propellant as a result of a new velocity increment budget. Changes in the inert weights contributed to the revised propellant requirements.

The Command Module weight increased 270 pounds. Major changes include miscellaneous structural changes, the addition of 284 pounds of wiring including 178 pounds of instrumentation wire and connectors, 89 pounds of crew couch structure and attenuation, 31 pounds of crushable honeycomb and 13 pounds of additional parachute weight in the Earth Landing System and deletion of the Portable Life Support System (PLSS) unit (-43 pounds) and 6 pounds of Environmental Control System expendables.

The Service Module weight decreased ten pounds. Major changes include miscellaneous increases of 5 pounds each in Environmental Control and Electrical Power Subsystems, a net change of +25 pounds to the Service Propulsion Subsystem resulting from the addition of a zero g retention device and reduction of wire, +22 pounds in the Reaction Control Subsystem for miscellaneous changes and additional insulation and a decrease of 67 pounds of electronics resulting primarily from decreased wire requirements.

Major changes affecting the LEM weight include the two tank ascent stage, staging of the Environmental Control Subsystem water tanks, a new landing gear, light-weight electronics and a reconfigured propellant system. Most of the changes resulted from the weight reduction study initiated in August 1964. The program to achieve additional reductions and control potential growth is continuing.

The increase in the Launch Escape System results from additional ballast required for stability during abort.

A similar study of Command and Service Module weights is being conducted. Feasible changes will be incorporated as quickly as possible; however, most changes of significant magnitude cannot be implemented on Block I spacecraft.

LEM - Descent Engine Crushing During Lunar Landing

Preliminary analysis of the latest descent engine nozzle configurations indicates that the crushing load may be higher than originally used during dynamic landing stability analysis. Average crushing loads higher than approximately 1,500 pounds would cause some worse case landings not to meet present stability requirements.

Areas being investigated toward resolution of this potential problem are:

1. Structural analysis of descent engine skirts to afford minimum average crushing load is being conducted by SMD at MSC.
2. GAEC is continuing load tests of small cones to augment buckling analysis.
3. GAEC is determining propellant weight penalty for reduction of engine skirt length.
4. MSC, SMD and ASTD are running analytical landing dynamic comparisons of other gear configuration that will fit within the present 336 inch adapter.
5. GAEC will begin drop tests of a 1/6 scale 180 inch radius tripod landing gear the latter part of April 1964.
6. Analytical landing stability analysis at GAEC for various landing conditions will include effects of descent engine crushing loads.

Environmental Control System

NAA has recommended the addition of an active thermal control system to the Service Module for Reaction Control System (RCS) and Service Propulsion System (SPS) temperature control in the deep space environment. The NAA recommended system is a freon circulation heat, transport loop consisting of appropriate heat transfer plates, valves, servo controllers, pumps, sensors, radiators, electric heaters, integrated with the primary environmental control system. NAA also recommends a slightly different active thermal control system for the RCS only for earth orbit flights.

An extensive thermal analysis has been conducted by MSC to evaluate the requirement for these systems. Results indicate that the active systems can be avoided by various passive changes to the Service Module structure, RCS engine and control of the spacecraft attitude. NAA was directed to stop work on the active systems and incorporate passive thermal control in the Service Module for the LOR mission.

MSC and NAA studies of the earth orbit requirements are continuing. Tight schedule constraints may make passive solution of this problem more difficult.

The cabin temperature control problem has been solved by the addition of the boost protection cover. This cover allows provision of a thermal coating over the Command Module surface thereby limiting environmental heat loads. This change avoided a potential weight increase of approximately 50 pounds to upgrade Environmental Control System capacity.

CREW INTEGRATION

Training

A review of the design status of the visual simulation system for the Apollo Mission Simulator (AMS) and the design criteria for problem areas was conducted January 28-29, 1964. The infinity image transfer system is 90% complete in mechanical design and 50-70% complete in the optical design varying with the landing and docking windows. The starfield image generation is complete except for mechanical installation details. The sextant, rendezvous and docking and mission effects subsystems are all in preliminary design or design review at Link and NAA. The pacing item in the visual system is still the Mission Effect Projector.

NAA and MSC training equipment personnel discussed G&N data requirements for training equipment with MIT personnel at an XTASI (Exchange of Technical Data for Simulation) meeting in Downey, February

12, 1964. NAA's performance in presenting its requirements was unsatisfactory. This and other indications create misgivings as to the adequacy of NAA's internal data procedures in the G&N area in particular and other areas as well. PE4 and RASPO are investigating the sources of the problem.

NAA has made a cost-effectiveness study of the Apollo Mission Simulator visual simulation system as presently designed in comparison with two systems potentially adequate and potentially less expensive and complex. Based on the study action has been taken to delete the hatch window system but maintain an interface which will allow later installation if desired.

Personnel from ASPO, NAA and Link attended a design review of the Simulation, Checkout and Training System (SCATS) of the Integrated Mission Control Center (IMCC), during the week of January 20-24. The general ground rules for the division of functions between the AMS and the IMCC have been defined. The basic booster simulation will be done in the IMCC with some body motion simulation in the AMS for certain modes of operation.

GAEC has completed revision of the specification for the LEM Mission Simulator. The RFQ was released on February 7 to eight companies, Link, ACF, Melpar, Goodyear, Curtiss-Wright, Ordnance Division of Minneapolis-Honeywell, Republic Aviation, and the Electronic Systems Division of MacDonnell Aircraft. On April 15 proposals were submitted by Melpar, Link, Curtis-Wright, Republic, and MacDonnell. GAEC and MSC are reviewing the proposals with May 15, 1964, as a target date for completion.

ASPO has approved Grumman's technical negotiation with Farrand for the LEM external visual simulation displays.

Familiarization courses were conducted at AMR during the weeks of February 10 and 17.

A short course (15 hours) at MIT the week of March 2, 1964, reviewed the SCS and the interfaces of the G&N and SCS. An extended course was provided AC Spark Plug field operations personnel between March 31 and April 8, 1964.

Centrifuge Tests

All data collection at Johnsville has been completed.

The fixture has been loaned to International Latex until April 1, 1964, to facilitate couch-suit interface studies. Major problems are in suit width and lateral expansion when pressurized.

Impact Limits

NAA has been provided revised crew tolerance impact limits which provide for higher onset rates and lower peak values, i.e. 1000 "g"/second and 20 g as opposed to 500 "g"/second and 25 g. These revisions will allow tradeoff studies between peak value and onset rates to improve system designs presently restricted by onset rate limits.

Crew Integration Branch completed negotiations with CSD personnel for CSD to exercise supervision and coordination of contractor zero gravity test activities for crew systems and crew interfaces to other systems. An Apollo Subsystem Management Agreement Change to support these discussions has been initiated.

On February 17 and 18, 1964, MSC personnel from ASPO, E&D, and FCSD reviewed the NAA task analysis computer programs which address the data bank for particular organizations of data. Three test exercises were formulated to evaluate the system in use and determine what MSC's future policy should be toward this effort. Initial results from these tests are satisfactory.

The LEM Test Model - 1 (TM-1) review was conducted at GAEC on March 24-26, 1964. Fifty-six chits were submitted for the twelve review areas. A report is being prepared to indicate the action taken for each Request for Change or Study.

Joint ASPO-FCSD effort has been initiated on the development of a series of ICD's for standardization of control-display functions, conventions, etc. for CM and LEM.

Controls and Displays

The astronauts have submitted their final report of recommendations based on six months of working session reviews of subsystem controls and displays. Implementation of the recommendations will be started during the current Block I/Block II configuration exercise.

RELIABILITY AND QUALITY ASSURANCE

RELIABILITY

Action was initiated with the Apollo Procurement Officer to implement NASA Reliability publication NPC 250-1, "Reliability Program Provisions for Space System Contractors," into the Apollo contracts with NAA, GAEC, MIT, and GD/C. Crew Systems Division was notified of this requirement and will implement NPC 250-1 into Phases D, E, and F of the Space Suit Contract with Hamilton Standard.

Reliability Assessments were conducted on BP-12 and BP-13. Results indicated the need for additional definitions to obtain a meaningful qualitative and quantitative reliability assessment.

The Reliability Plans for ACE-S/C contractors Radiation, Inc. and Control Data Corp. were approved after being rewritten at ASPO direction.

ASPO recommended to OMSF that R-11, Apollo Reliability Prediction, Estimation, and Evaluation Guidelines, be made a requirement rather than a guideline document. Comments were submitted to OMSF.

ASPO has prepared an outline for the ASPO Reliability Program Plan. Final Plan is contingent on release of OMSF R&QA Plan.

Failure mode and effects analysis (FMEA) were discussed with NAA & MIT (AC Spark Plug) to attempt to establish a common format to allow performing FMEA on each block (design) of vehicles and on each flight vehicle, exclusive of boilerplates and ground test vehicles.

Investigation has been initiated into the reliability interfaces between NAA and GE to establish the reliability status of ACE-S/C carry-on equipment. NAA has been instructed to investigate the reliability interfaces with MIT and GAEC and take whatever action is due immediately.

QUALITY ASSURANCE

NASA Headquarters proposed Quality Publication, 200-Y, "Quality Requirements for Hand Soldering of Electrical Connections," was reviewed and concurred in by ASPO.

Quality assurance requirements were prepared for Phases D, E, and F of the Space Suit Contract and forwarded to Crew Systems Division for inclusion into Contract NAS 9-723 when these phases are negotiated.

Quality Assurance and Inspection requirements for ASPO support at WSMR were prepared and are currently being reviewed prior to implementation.

A meeting was conducted to discuss with contractors the ASPO Acceptance Data Package format. A revised format has been prepared as a result of this meeting, submitted to the Apollo contractors, to be utilized for acceptance of all Apollo hardware.

SPACECRAFT TEST

GROUND TEST ARTICLES

Boilerplate 1, Boilerplate 2

These vehicles are undergoing a modification and test preparation period. The Phase II drop program in support of couch attenuation system development will begin approximately April 15, 1964.

Boilerplate 14 - House Spacecraft No. 1

Structural fabrication was completed during the past quarter on schedule. Final installation and checkout of systems has been delayed due to late delivery of subsystem components. Most critical items are components in the Electrical Power (EPS), Communications, Environmental Control and Reaction Control Systems. Ground Support Equipment availability schedules are generally compatible with the current test plan sequence and schedules. Individual system tests on the EPS will start in mid-June 1964. Late arrival components of other systems will be installed concurrently with testing on a non-interference basis to regain as much of the schedule as possible before start of combined system and integrated system testing.

Boilerplate 28

Final delivery of this vehicle to be July 31, 1964 to Engineering Development Laboratory. Subsequent to test preparation period of approximately 60 days drop testing will begin approximately October 1, 1964. This vehicle is now pacing the impact drop test program item.

Airframe 001 (Service Module Only)

Airframe 001 Service Module's primary structure was completed by mid-January 1964. The Service Module's electrical wire harness mockup was completed in late January 1964. During the attempt to fit-check the mockup into the Service Module on January 31, it was discovered that the holes in the primary structure were too small to allow passage of the harness with its associated connectors. The primary structure had been designed to the original electrical wire bundle of 606 wires. However, the number of wires had increased from 606 to approximately 1200 wires subsequent to the completion of the primary structure design. To correct this problem the passageway in the following areas had to be enlarged: the forward bulkhead, the three cryogenic shelves, and the lower bulkhead. Also the primary and secondary structure had to be strengthened and raceways had to be added to support the harness.

The above work was completed and the electrical harness mockup fit-check was completed by March 14, 1964 along with SPS propellant tanks, helium storage bottles, fuel cells, and cryogenic tanks. The above components have been removed from the Service Module to allow completion of the EPS ECS tubing mockup.

The status of the Service Module in manufacturing remains the same as reported last quarter, that is, approximately five months behind schedule when compared to Master Development Schedule No. 7. It is anticipated that manufacturing will be completed by mid-August 1964, the Service Module shipped to the Propulsion Systems Development Facility by October 1964, and testing to be initiated in January 1965.

Airframe 004 and 005

This vehicle will be released from manufacturing approximately three months/MDS-7 because of assembly line jig, tooling, and schedule problems.

AFRM 006 - House Spacecraft No. 2

Fabrication of structural details was completed since the last report and subassembly of structure is nearing completion. Command Module is estimated to be approximately 12 weeks behind schedule due to unscheduled rework necessary to correct tooling discrepancies and repair of honeycomb bonding voids. Rework has been completed and contractor is implementing a fabrication schedule recovery program to regain as much time as possible. Insufficient time has elapsed since completion of rework to evaluate the validity of the recovery plans.

Transfer of the AFRM 006 acoustic test program to the AFRM 007 vehicle has been implemented. This appears to offset the delay in fabrication and will allow start of systems vibration tests on July 1, 1964 as planned. Current vibration program is estimated to require approximately four months for completion.

Airframe 007

This vehicle will be released frommanufacturing approximately three months late/MDS-7 because of assembly line jig, tooling, and schedule problems. This vehicle has also been assigned the acoustical test program and therefore it is doubtful it can successfully support the impact test program prior to flight of AFRM 009.

AFRM 008

Manufacturing. AFRM 008 is in subassembly stages of manufacturing. 552 of the 562 CM basic structure drawings and 347 of the 348 CM secondary structure drawings have been released. With respect to the SM, all basic structure drawings have been released and 283 out of 288 secondary structure drawings have been released. Installation drawings are approximately 75 percent complete. The major manufacturing pacing item, with respect to hardware, is "Aeronca" CM panel delivery. The most significant manufacturing pacing item is that of the present tooling certification problem which is affecting all spacecraft now in manufacturing. NAA-Manufacturing is presently reporting a 14 week slip in the AFRM 008 manufacturing schedule due to these problems.

PERT, Milestones, etc. Instrumentation, specifically that of R&D Instrumentation, continues to remain the most critical negative slack item. Procurement request release and long lead time delivery items are alleged to be the major cause of this problem. *March 27 PERT print-outs reflect 31.2 weeks slack.

Thermal Vacuum (T/V) Subprogram. On February 27, 1964, NAA presented to MSC their revised T/V Subprogram test concept. This concept reflected the philosophy and information contained in the CSM/LEM Integrated Test Plan, SID64-66. ASPO-Integrated Systems Ground Test (PT-3) concurs with the NAA concept and will further review it at the next NAA T/V Subprogram presentation in May. A more comprehensive review of the T/V Subprogram is pending release of the detailed test plan which is unofficially scheduled for release in July.

Logistics. The NAA/MSC Apollo Logistics Task Group was given a presentation (3-4-64) on the MSC-Space Environment Simulation Laboratory (SESL) for purposes of further defining the logistics support requirements of the T/V test program. NAA logistics personnel are now working directly with SESL personnel for purposes of evolving a finalized logistic support plan for the SESL.

FLIGHT TEST ARTICLES

Boilerplate 6

Boilerplate 6 is being re-cycled into recovery system development program. It is currently at NAA being modified for drop testing. The Postlaunch Memorandum Report has been issued and distributed. Reporting on this vehicle in this section of the report will be discontinued.

Boilerplate 12

During this reporting period, BP-12 successfully completed in-plant checkout at Downey and arrived at WSMR on 28 February 1964. Assembly of the launch escape system with the live motors and final parachute installation on the command module was completed and the boilerplate was mated to the Little Joe II on the launch pad on 30 March 1964. Electrical checkout is proceeding at this time. Modifications to the launch escape system sequencer has caused a two week delay in the launch schedule. The first modification was necessitated by the addition of relays to eliminate a potential single point failure. A second modification was later required to protect two time delay relays from the effects of negative voltage transients. While awaiting the latest configuration launch escape system sequencer, a dormant monitor system will be installed and several potential single point failures will be eliminated in the test vehicle and landline network. The integrated launch schedule has been adjusted to cause a minimum delay in the launch preparations. The present anticipated launch date is 12 May 1964.

Major decisions made during this reporting period were the decision to incorporate the above mentioned modifications and the decision not to install the launch escape system canard configuration on BP-12.

Little Joe II (Launch Vehicle 12-50-2)

During this reporting period, Little Joe II Launch Vehicle 12-50-2 completed factory checkout on 11 February 1964 and was delivered on dock at WSMR on 17 February 1964. Field preparations for the A-001 Mission were subsequently started. Receiving inspections were completed and the launch vehicle was erected on the launcher. Recruit and Algol rocket motors were installed and the launcher elevation azimuth positioning system was functionally verified. Modifications to the thrust termination system and umbilical wiring were instituted to alleviate potential single point failures and are scheduled to be completed by mid-April. The payload was mated to the launch vehicle on 30 March 1964 with integrated system checkout scheduled to commence on 27 April 1964.

For further information on the launch preparation for the A-001 Mission, see the BP-12 portion of this report.

Boilerplate 22

Subassembly of Boilerplate 22 is continuing. The hockey stick longerons, which were the pacing item last quarter, have been delivered and schedule impact due to this item is no longer a problem. The wiring harness which is still at Slauson, shows some negative slack. The harness was not delivered on time due to some late engineering releases. A maximum effort is being made to preclude any assembly schedule loss.

It was decided during this quarter that the canard configuration would be retrofitted into this boilerplate. The workload at NAA of configuring all vehicles with canards plus re-configuring BP-23 and scheduling it to fly before BP-22 could have some effect on the scheduled launch date of BP-22. NASA is encouraging NAA to schedule the two flights so that both can be supported by NAA and NASA.

Boilerplate 23

Boilerplate 23 completed manufacturing during this reporting period. A Design Engineering Inspection was held on 29 January 1964, and a total of 29 Requests for Change were submitted to the contractor. Requests for Change and NAA updating work is still in progress. It is anticipated that BP-23 will no longer be a backup for BP-12, but will be assigned a new mission. It will be re-configured with the addition of a rocket canard, dual drogues, sequencer modifications and a boost protective cover. The new configuration and mission is now under study at NAA and MSC. A date in December of 1964 is now the target date for launch.

Airframe 002

The schedule of work being accomplished on the fabrication of this vehicle is unclear due to tooling difficulties experienced at the NAA plant. There has been at least a verbal report from NAA that this vehicle completion will slip from 14 August 1964 to 1 December 1964. The exact reasons for this slippage are not available. All outside honeycomb panels have been delivered to NAA. All other major items such as parachutes, motors, etc. appear to support MDS-7. The Minneapolis Honeywell stabilization control systems may be 1 to 1-1/2 weeks behind schedule.

Airframe 010

This vehicle has the same schedule problems as AFRM 002. The launch escape tower is not in schedule for work. The Command Module detailed fabrication is progressing as well as available tooling will allow. Subassembly now in work is scheduled to be completed 4 December 1964. Major end items. such as motors, parachutes, etc. are ahead of schedule in delivery with the exception of the outside honeycomb panels which are 2-1/2 to 3 weeks behind schedule.

BP-13

The spacecraft mating in the vertical test tower was completed January 16 in preparation for conducting the Integrated Systems checkout. The GSE Integrated checkout was started January 20 and was satisfactorily completed January 23. The Integrated Systems checkout was initiated on January 30 and was satisfactorily completed February 5. Shipment of the spacecraft modules and GSE to AMR was started February 13, with the final aircraft load arriving at AMR February 19. Upon arrival at AMR, both the GSE and the spacecraft modules underwent a receiving inspection and then were installed in the predesignated locations. A Hanger GSE-Complex Compatibility checkout was completed on March 4. A Spacecraft Complex Compatibility checkout was initiated March 9 and was completed March 11.

A configuration change from the dual-mode to the single-mode explosive bolts in the Launch Escape System was completed. A reduction in the spacecraft weight by 1600 pounds was accomplished by removal of ballast from the service module and adapter. This was a result of a decrease in the orbital payload capability of the booster. The Integrated Systems checkout -

Hanger AF, was started March 25 and was satisfactorily completed the same day. This was the final test in Hanger AF prior to moving the spacecraft to Launch Complex 37B.

The spacecraft and LES were moved to Complex 37 on April 2 and mated with the SA-6 booster. Preparations are underway to start GSE and spacecraft systems testing in the mated configuration.

BP-15

A fit check was accomplished on the spacecraft modules on January 14, 1964. The BP-15 design engineering inspection was held on January 30, 1964.

The spacecraft was officially accepted by the NAA Apollo Test and Operations area on March 6, 1964. Subsequently, modification work has been accomplished in preparation for start of individual systems tests.

The work accomplished in the modification period included relocation of the SM and adapter fluctuating pressure transducers.

A span of 62 days for checkout in ATO is presently planned.

BP-16

NAA proposed a plan of action for checkout of BP-16 C/M. The plan proposed using some GSE from BP-13 and BP-15 to provide a shipping date on or about June 26, 1964. The logic of the plan was approved. The ability to meet shipping date was questioned.

BP-26

The BP-26 SM, adapter and associated GSE were delivered on schedule, March 16, 1964, to MSFC.

BOILERPLATE NO. 27 - SECOND SATURN APOLLO DYNAMIC TEST ARTICLE

Reorientation of the Saturn I/Apollo Space Vehicle program resulted in revised MSFC Dynamic Test scheduling and payload requirements. The Apollo/S-IV Instrument Unit (I.U.) adapter for BP 27 has been cancelled and MSFC requested that the Launch Escape System (LES), Command and Service Modules be delivered on or before December 1, 1964. MSFC delivery is presently scheduled for mid-November, 1964 to ensure ample time for installation of test instrumentation.

Manufacturing completion of the S-IV-B I.U. is scheduled for mid-January 1965. MSFC has requested the adapter be available in Huntsville on or before January 15, 1965. This does not appear to present a problem at this time.

LTA-2 SATURN APOLLO DYNAMIC TEST ARTICLE

Contract Change Authorization (CCA) No. 28 was issued to implement necessary changes to the ballast arrangement and improve the delivery schedule to meet revised MSFC test requirements. Vehicle is now required at MSFC on or before December 1, 1965 and is currently scheduled for delivery in mid-November to insure ample time for installation of MSFC test instrumentation.

LAUNCH VEHICLE DEVELOPMENT

Little Joe II

Convair has completed manufacture on all of the four Little Joe II vehicles without control systems. The second vehicle was shipped to WSMR in February to support the initial spacecraft flight (BP-12) the third and fourth vehicles have been placed in storage until required to support the spacecraft flight tests. The first of four vehicles with control systems (vehicle No. 5) is nearly complete and will be placed in storage in May. Work is progressing on schedule for the other three vehicles with control systems (vehicle Nos. 6, 7, & 8). Vehicles will be placed in storage without motor ignition harnesses since the exact test conditions and numbers of motors required are not known.

A fixed price incentive type contract was negotiated with Aerojet in March for twelve additional rocket motors with canted nozzles to partially support the four vehicles with control systems. Additional rocket motors will be ordered when the exact test conditions and numbers of motors required are known for all of these vehicles.

Convair has completed integrated control system tests. Tests were made with control system hardware replacing components simulated on analog computer during earlier tests. Vibration tests of reaction control motor module have been delayed by availability of facilities. Delay is not expected to affect schedule flight tests.

OPERATIONS PLANNING

Grumman Mission Planning Study

At the request of the Apollo Spacecraft Program Office, Grumman has initiated a special study of the mission requirements associated with the entire lunar landing mission.

The principal objectives of this study are:

a. Determine the mission-related, functional requirements for the spacecraft subsystems, and examine the present subsystem capabilities relative to these functional requirements for both nominal and contingency situations.

b. Evaluate the capability of the spacecraft to fly missions which meet the mission objectives and determine the flexibilities available within the established control weights.

c. Provide the program with mission plans which can be the basis for other analyses and reporting.

A preliminary Reference Mission has been developed and approximately twenty supporting studies have been initiated to explore the detailed mission requirements. As the study proceeds, analysis of performance requirements, mission-related constraints and other supporting studies will form the basis for a Control Weight Mission and subsystem Critical Design Missions which, in turn, will define mission-related subsystem design criteria.

Apollo Systems Specification M-DM 8000.001

Copies of sections 4.4, 4.5 and 4.8 of the Apollo System Specification were received and forwarded to all holders of this document.

The Operations Planning Division is currently studying the remaining discrepancies between the current spacecraft design and the System Specification. Results of these studies will aid in the determination of whether to change the spacecraft design or to request changes of the Manned Space Flight (MSF) Specification. These discrepancy studies are scheduled to be completed by June 1, 1964. To date, the following items have been resolved by changes in the MSF Specification.

a. The requirement to track the spacecraft continuously from second S-IVB ignition through completion of burn has been eliminated from MSF Specification.

b. The requirement for sending ground data simultaneously to the Command and Service Module (CSM) and the Lunar Excursion Module (LEM) has been changed to sending ground data sequentially.

c. The communications distance on the lunar surface has been changed to three nautical miles in MSF Specification.

d. The requirement to transmit from an extravehicular astronaut on the lunar surface directly to the CSM in lunar orbit has been replaced by the requirement to transmit from astronaut on lunar surface to CSM in lunar orbit via the LEM relay.

The main purpose of the preliminary Reference Mission is to provide a framework upon which to begin assessing the current capabilities of the spacecraft while the more precise Control Weight and Subsystem Critical Design Missions are being defined. The Control Weight Mission is characterized by its stringent performance requirements on the spacecraft; hence, the ability to perform the Control Weight Mission assures the ability to perform a variety of lesser missions. The Control Weight Mission will then be used as a basis for a variety of tasks, such as weight reporting, reliability modeling, contingency analyses, and trade-off studies.

During the next quarter, a Control Weight Mission trajectory will be selected, and the sequence-of-events developed for the Reference Mission will be re-indexed to the Control Weight Mission. As the Study progresses, the sequence-of-events will continue to be developed in greater detail. Effort currently underway on the contingency analysis will continue to be emphasized. In addition, work will begin on the development of Subsystems Critical Design Missions.

In addition to the discrepancies, study effort on the design objectives has also been initiated with resolution of all objectives currently scheduled to be completed by August 1, 1964. To date the following design objectives were incorporated as firm requirements into the Apollo Specification.

a. The CSM shall be equipped with a radar capable of tracking the LEM.

b. Conference capability between lunar explorer, an astronaut in the LEM, and the earth shall be provided.

General Requirements

During this quarter, the Operations Planning Division has been requested to define operational requirements in a variety of areas. This division's activities in several of these areas are summarized below:

Communications. -

It was established that:

a. NAA should conduct the necessary investigation and analysis to develop an implementation plan for a hard copy printout. A Contract Change Authorization (CCA) was approved for this study effort.

b. There is no requirement for a direct communications link from S-IVB/LEM to CSM during transposition.

c. TV from LEM should be furnished during LEM ascent and descent phases as well as during lunar surface operations.

d. Recording of LEM data will be accomplished in the CM data storage equipment, thus eliminating requirement for data storage equipment in LEM.

e. LEM communication system is not required to function prior to LEM transposition.

Attitude Control.-

It was established that it is reasonable to take design advantage of spacecraft orientations to reduce thermal problems. The following operational constraints must be considered:

a. Communications with ground should not be broken unexpectedly.

b. No launch opportunities lost due to sun location.

c. Astronauts should not be required to control or monitor attitude continuously.

d. A monitoring system is provided for the critical temperature points.

Launch Window Constraints.-

General Electric Apollo Support is exploring the problems posed by "random" factors constraining launch window availability. These factors include launch site weather, solar flares and landing area weather. The results of this study will be fed into the trajectory and lighting constraint work being carried out by Flight Operations Division (FOD).

Range Safety

The following operational requirements have been established for the Service Module (SM) propellant dispersal system.

a. The SM propellant dispersal system shall be rendered inoperable by positive means in flight at the earliest time acceptable to the Range Safety Officer, and no later than launch escape tower jettison.

b. The SM propellant dispersal system shall not be attached to the spacecraft after it is separated from the launch vehicle.

c. Only SM propulsion system propellants require dispersal by the SM propellant dispersal system.

d. One SM propellant dispersal system design shall be capable for use on all SM's launched containing propellants; i.e., Saturn IB and Saturn V flights.

e. The SM propellant dispersal system design effort shall first consider utilization of appropriate elements of the launch vehicle destruct system, then consider a system totally independent from the launch vehicle.

f. The SM propellant dispersal system shall be inoperable while the Command Module (CM) and Service Module (SM) are connected if the destruct system is independent from the launch vehicle.

g. The SM propellant dispersal system crew safety reliability shall be absorbed in the existing spacecraft crew safety reliability apportionment.

h. The first effectivity for the SM propellant dispersal system shall be for the first SM launched containing SM propulsion system propellants.

No range safety requirement currently exists for a LEM propellant dispersal system. This matter remains under active study by both the Manned Spacecraft Center (MSC) and the Kennedy Space Center (KSC).

ACE-S/C PROJECT OFFICE

During the last quarter General Electric Company was set up as an associate contractor for ACE-S/C, with operating headquarters in Daytona Beach, Florida. The RASPO has also been established and Mr. S. P. Hale has been named Manager.

In January a decision was reached to provide two ACE-S/C Stations for Houston instead of the proposed 1-3/4 Stations. This allows the utilization of all the hardware with the software package used at the other sites. This brings the total number of stations up to 10. Currently, GE is proceeding with making the first Houston Station a "Chinese copy" of the NAA Station, plus three consoles to handle special measurements for thermal vacuum and aero-med. Preliminary Interface Control Documents (ICD's) have been released.

In February, the milestone charts for NAA Station and the PERT charts indicated that GE was four weeks behind schedule. The major problem was that the wiring required turned out to be twice as much as was originally anticipated. By April 1, after streamlining the procurement cycle and putting GE on two shifts, and changing the test cycle, a marked improvement in schedule was shown. It now stands at about -.5 week.

During this quarter Control Data Corporation finished its acceptance test of the 160G computer. It ran through 168 hours non-stop without any failure. The computers have been shipped to the Experimental Station at Cape Kennedy. These units have now undergone installation and have been checked out by CDC personnel and are operational.

In the training area for ACE-S/C arrangements were made with CDC for a nine-week course on Maintenance and Operations to begin on March 30, 1964. GE personnel are attending this course. A Programming Course began on April 6 with GE and NAA attendees. The ACE-S/C Operator Course has been established. This course will consist of one week for the NAA-MIT-GAEC test engineers and one week for the operators.

In late February, a review of the NAA carry-on equipment schedule indicated that ACE-S/C activation, due to NAA carry-on equipment being late, is now shifted to August 15, 1964. This is a two-week slippage for the carry-on. NAA states that they will now be able to support 009 with ACE-S/C and that they will not need additional STU's to perform this job.

On February 11, 1964, the first GE/GAEC meeting was held on ACE-S/C at which time schedules were worked out for ICD's at the GAEC installation.

All NAA ICD's have been released by GE to NAA.

During this period a better definition has been achieved between ACE-S/C and ACE-L/V. The ACE-L/V - ACE-S/C Interface Control Document has been completed and submitted to MSFC for approval.

GE quotation for the 10 ACE-S/C Ground Stations and support has been submitted to NASA. Negotiations are scheduled for the coming month.

PROGRAM CONTROL

Ground Support Equipment (GSE)

The major portion of the report period was involved in evaluating the GSE design and development efforts of NAA, GAEC, and MIT, coordinating the requirements of WSMR, AMR and other MSC activities with those of the contractors, and making design recommendations and developing design criteria.

GSE Flow Diagrams for AFRM 006 and 010 have been reviewed and the comments transmitted to NAA.

The GSE Requirements Review Control Procedure was issued to provide the basis for review of GSE end items and establishes a definition of documentation requirements to satisfy the procedure.

The list of GSE which is common between the LEM and the C & SM and which will be supplied to GAEC as GFE has been finished and transmitted to GAEC. 32 items have been identified as such.

The GSE Requirements Review Procedure was forwarded to NAA, GAEC, and MIT for implementation. A requirements review board will be established to act for MSC at the requirements and concept reviews.

A NAA GSE end item specification format was prepared to replace the existing one. The major change involves modifications to GSE prior to acceptance by NASA, in which case, the modification will be accomplished by the EO procedure, rather than Fig. "A".

A complete list of GSE, broken down by sub-systems, was compiled and delivered to E&D. Same list has been transmitted to F.O., for the purpose of assigning personnel to these pieces of GSE for monitoring and review.

A recommendation was made to cancel the three (3) S14-001 Module Leak Test Units as the tests originally scheduled for these units can be accomplished with a Wallace and Tiernan Pressure Guage and an S14-079 Module Leak Test Unit.

A meeting was held on March 12, 1964, with AC Spark Plug PERT personnel to discuss GSE reporting requirements that could be satisfied by use of the PERT system.

Apollo GSE General Environmental Criteria and Test Specification MSC-GSE-1B superseded MSC-GSE-1A and was released into the NAA, GAEC, and MIT.

The Ground Support Equipment Design Specification (MSC-GSE-F-11) was incorporated into the Apollo GAEC program in lieu of GAEC GSE Procurement, Design Control, and End Item Specification.

About 80 new pieces of GSE have been identified.

Facilities

GAEC request for Government furnished ground data station at Bethpage has been reviewed. NASA will supply the required data reduction equipment after approving detail design and development schedules submitted by GAEC.

A detail design study has been initiated by NASA/MSC to provide a data ground station at WSMR/PSDF. This facility is to be used to reduce development data generated from the WSMR/PSDF.

The Common Use Laboratory concept for WSMR/PSDF has been approved. Funds for advance design of the building have been approved by NASA Hq. Construction funds have not been approved yet. The building is presently scheduled for occupancy November, 1964, based on April, 1964 approval of construction funds .

Laboratory and test equipment to furnish the WSMR/PSDF common use laboratory has been placed on order. Some of the equipment will be installed in temporary facilities, pending completion of the common use laboratory.

Facilities/GSE Site Activation

The NAA/S&ID has been selected to accomplish Facilities/GSE Site Activation for Apollo test programs at NAA/Downey, WSMR/PSDF, MSC/Houston and MSC/MILA. NAA is responsible for coordinating requirements, design, schedules, and making installations as defined for each test site.

NAA has made a proposal of the level of effort required to accomplish the Facilities/GSE site activation effort. Final negotiation on the proposal is scheduled for next month.

Logistics

An airlift transportation schedule was prepared and issued to all contractors using Air Force C-133B and Aero Spacelines B-377PG aircraft to transport Apollo equipment.

NAA and GAEC Maintenance plans were reviewed. Each contractor was given guidelines and direction to submit revised plans by May 1, 1964.

The NAA Packing and Transport Plan for Apollo was reviewed and approved.

The NAA Government Furnished Property (GFR) list was reviewed and revised to identify current requirements, quantities and need dates to support NAA activities at the various test sites.

TABLE I - APOLLO SPACECRAFT WEIGHT STATUS

LUNAR ORBIT RENDEZVOUS MISSION

	CONTROL WEIGHT LBS.	TARGET WEIGHT LBS.	CURRENT STATUS LBS.	CHANGES FROM LAST REPORT
A. Command Module (Incl. Crew)	9,500	8,500	10,040	+ 270
B. Service Module				
Inert	10,500	9,000	9,950	- 10
Usable Propellant - Translunar ($\Delta V_1 = 3870$ fps; Isp = 313 sec)	27,600	24,015	26,505	-2,745
Usable Propellant - Transearth ($\Delta V_2 = 3915$ fps; Isp = 313 sec)	9,500	8,310	9,495	-2,540
TOTAL	47,600	41,325	45,950	-5,295
C. LUNAR EXCURSION MODULE (W/O Enc.)				
Descent Stage				
- Inert (Incl. Residuals)	3,400	3,200	3,650	+ 185
- Usable Propellant ($\Delta V_3 = 7385$ fps; Isp = 301 sec)	15,920	13,780	14,662	-2,243
Ascent Stage				
- Inert (Incl. Residuals)	5,000	4,170	4,323	- 677
- Usable Propellant ($\Delta V_4 = 6646$ fps; Isp = 303 sec)	5,180	4,350	4,514	- 581
TOTAL	29,500	25,500	27,149	-3,316
D. Adapter	3,400	3,100	3,400	0
E. Total Spacecraft Injected Weight	90,000	78,425	86,539	-8,341
Launch Escape System	6,600	6,500	7,275	+ 60
TOTAL SPACECRAFT LAUNCH WEIGHT	96,600	84,925	93,814	-8,281